1966

TECHNICAL HIGHLIGHTS

OF THE

NATIONAL BUREAU OF STANDARDS

Annual Report for:

INSTITUTE FOR BASIC STANDARDS

INSTITUTE FOR MATERIALS RESEARCH

INSTITUTE FOR APPLIED TECHNOLOGY

UNITED STATES DEPARTMENT OF COMMERCE
John T. Connor, *Secretary*
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NATIONAL BUREAU OF STANDARDS
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1966
Technical Highlights
of the
National Bureau of Standards

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DIRECTOR'S STATEMENT

MANAGEMENT PROGRESS

During the 1966 fiscal year several management changes were made which will help the Bureau better to fulfill its primary responsibilities. These changes were primarily required by the constantly changing state of science and technology. The central mission of the Bureau has remained substantially unchanged, but external factors in government, industry, and commerce have required adjustments in orientation and emphasis for the NBS staff. Several of these are described below.

Transfer of Programs to ESSA

The primary organizational change was the formal transfer in October of the Bureau's Central Radio Propagation Laboratory (CRPL) in Boulder, Colo., to the Commerce Department's new Environmental Science Services Administration (ESSA). ESSA is the result of a reorganization and combining of CRPL, Weather Bureau, and the Coast and Geodetic Survey.

In addition to the transfer of CRPL, a new Geoacoustics Group was formed in ESSA's Institute for Telecommunication Sciences and Aeronomy by the transfer of fifteen staff members from the NBS Sound Section. This group will continue studies of the propagation of sound waves through the atmosphere and other media and investigations of the interactions between sound waves and other geophysical phenomena.

Program-Planning-Budgeting Activities

Implementation of the newly promulgated Government-wide Program-Planning-Budgeting System at NBS began in December 1965. A series of meetings was held to identify program categories appropriate to the Bureau's output, to examine related resource needs, to identify pertinent program issues, and to plan and initiate additional studies and activities as needed. The categorization of Bureau programs went through a series of revisions as a result of management study and discussion. Program memoranda describing the Bureau's activities, objectives and plans, together with a Program and Financial Plan projecting

costs for the next five years, were submitted to the Department of Commerce and the Bureau of the Budget on May 1. Most of the Bureau's programs were classified either under the category "Advancement of the Economy through Industry and Commerce" or the "Basic Measurements System."

Office of Engineering Standards Liaison and Analysis Established

An Office of Engineering Standards Liaison and Analysis was established to serve as a focal point for NBS assistance to engineering standards-making bodies throughout the Nation. The new Office will aid in making the Bureau's technical resources available to strengthen private standards organizations, manufacturers, and government agencies concerned with the development of performance standards and test methods for industrial products.

The Bureau has always played a key supporting role in the development of engineering standards (specifications, standards of practice, and methods of test) for technological devices, products, and services. Most of this work has been done in cooperation with technical societies and standardization groups such as the United States of America Standards Institute and the American Society for Testing and Materials. Normally the Bureau assists by providing expert advice and technical assistance on both national and international engineering standards committees.

In recent years there has been a growing awareness of the importance of engineering standards, both domestic and international, to the economic development of the country. This feeling has been strengthened within the past year by the publication of the recommendations of the Department of Commerce Panel on Engineering and Commodity Standards, under the chairmanship of Francis L. LaQue. Among other things, the Panel recommended greater participation by Federal agencies in certain aspects of the development of engineering standards by nongovernmental organizations, recognition of the importance that U. S. industry's participation in international standardization can have on the national economy, and communication of the importance of such participation to industry.

The Office of Engineering Standards Liaison and Analysis will aid in the achievement of these objectives through a program of active liaison with other standardizing organizations and by general review and analysis of the engineering standardization activities of the Bureau staff. It will endeavor to find new ways to increase the effectiveness of NBS technical assistance in the development of engineering standards and to match NBS technical resources to the needs of outside organizations. It will also

make a continuous effort to extend and improve communication between the Bureau and other engineering standards bodies so that NBS may know and respond to their needs and so that NBS capabilities in various technical fields may be better known to them.

Legislation Affecting the Bureau

Several pieces of legislation were considered by the Congress which are related to the responsibilities and activities of the Bureau. A bill authorizing the Bureau to make a study of the metric system was introduced and members of the NBS staff offered testimony before the House Committee on Science and Astronautics and the Senate Commerce Committee. Also, NBS participated in a number of studies associated with the hearings on automobile and traffic safety legislation.

The Bureau itself proposed a bill to provide a Standard Reference Data System. Part of the Statement of Purpose and Need reads:

"The Federal Council for Science and Technology announced in 1963 a policy that there should be established a National Standard Reference Data System to provide on a national basis critically evaluated data in the physical sciences. The Department of Commerce, through the National Bureau of Standards, established a program to assist in furthering this policy. The basic objective of that action was to make critically evaluated qualitative data on the properties of substances readily available to Federal technical agencies and this country's scientists and engineers.

"The proposed legislation is needed in order to provide the legal framework for a program to produce compilations of critically evaluated data on the properties of substances and their interactions, gathered from research reports throughout the world, evaluated by experts, and disseminated to the technical community. Through this legislation the voluntary and cooperative activities of all those concerned with the reference data program could be fitted into a coherent and comprehensive pattern so as to assure maximum benefit to the entire governmental and non-governmental community. The bill would also authorize the use of a symbol or mark in connection with the term "Standard Reference Data" so that the products of this interagency program can be identified and relied upon by the scientific, engineering and industrial communities.

"Compilations carried out other than by the National Bureau of Standards may become a part of the Standard Reference Data System through the voluntary efforts of the agencies and if they meet the standards prescribed by the Secretary of Commerce through the National Bureau of Standards. Through this voluntary cooperative arrangement and the activities of the National Bureau of Standards, it will be possible to provide to the technical community critically evaluated data which will lead to substantial savings in time, effort and money.

"The significance of the Standard Reference Data operation can best be understood by a look at the process by which measurements of the properties of substances are made available to scientists and engineers. Property measurements are produced as a result of the research done by millions of scientists and engineers all over the world. The data are published in

various scientific journals, reports, handbooks, and so forth. Therefore, while these data are available to anyone who is prepared to search the literature to find them, it is quite often difficult to locate a specific number or value in the millions of pages of scientific literature. Of equal importance is the fact that once the number or value is located, it is difficult to determine just how reliable such information is. A complicating factor is that often more than one researcher works in the same field each developing his own number or value for the same property. Only a specialist in the field can tell which is most likely to be correct. Accordingly, the Standard Reference Data System has as its purpose three main functions:

1. Extract the necessary data from the literature;
2. Determine the data's accuracy and reliability through a process of critical evaluation; and
3. Make the evaluated data readily avilable to users.

"The data are called 'reference' because scientists and engineers repeatedly refer to the data in their work. They are called 'standard' because differing values are critically evaluated by the most competent scientists in the field who then select and certify a single value or range of values as the best or 'standard' one. The data may then be used with maximum confidence, for rather than having to make independent measurements of physical and chemical characteristics of materials, scientists and engineers would be able to refer to the Standard Reference Data and depend upon the reliability of the measurements which have already been made and critically evaluated."

Public Law 89–306 passed on October 30, 1965, makes the Bureau responsible for providing technical support to the General Services Administration, the Bureau of the Budget, the Civil Service Commission, and all other Federal agencies in a program to increase cost effectiveness in the entire Federal Government's use of computers and associated equipment and procedures.

It also requires the Department of Commerce to make recommendations to the President "relating to the establishment of uniform Federal automatic data processing standards" and to undertake research, as required, in support of the advisory and standards functions.

To carry out the new responsibilities most effectively the Bureau established in September 1965 a new Center for Computer Sciences and Technology. This Center was made responsible for the functions assigned to the Secretary of Commerce by the Bureau of the Budget and Public Law 89–306.

The Center aids Government agencies in achieving greater value for the public's dollar in the selection, acquisition, and utilization of automatic data processing equipment. It also:

1. Provides advisory and consulting services to Government branches in developing computer systems.
2. Conducts research on computer sciences and information systems design.
3. Guides an executive branch program to develop, measure, and test voluntary computer standards.
4. Recommends uniform standards for automatic data proc-

essing equipment, techniques, and languages for equipment and services procured by the Federal Government.

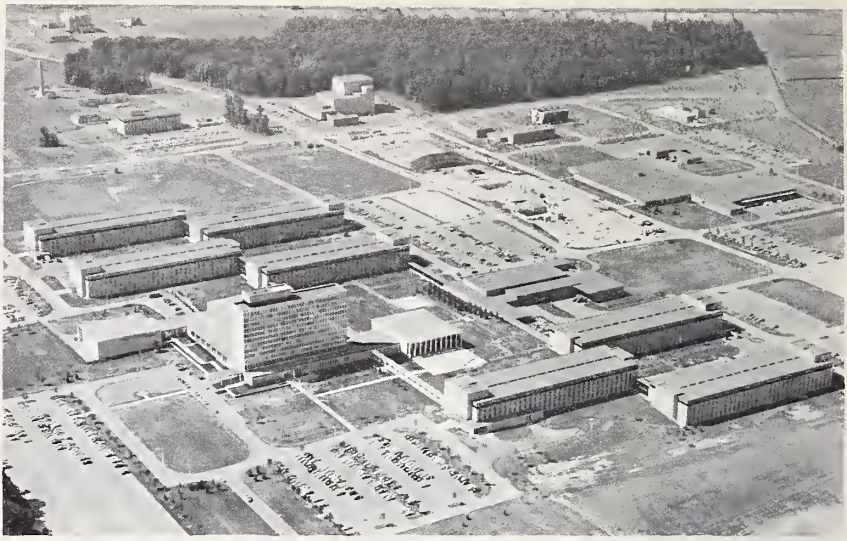
In September of 1965 the Congress passed the State Technical Services Act which authorizes and directs the Secretary of Commerce to aid State-designated agencies in carrying out their technological services programs by providing access to scientific, technical and engineering information from sources outside the State. In response to this directive, the Office of State Technical Services engaged the services of the NBS Clearinghouse for the purpose of preparing several forms of informational assistance to the designated agencies and participating institutions. A number of compendia and guidebooks were prepared under this arrangement and furnished to the States through OSTS on a complimentary basis. The regular services of the Clearinghouse, as an existing resource, were also available to the States on a nominal self-supporting basis. The Clearinghouse will also provide specialized reference services as the needs of the States become more clearly identified through surveys now being made.

THE MOVE TO GAITHERSBURG

NBS OCCUPIES NEW FACILITY

By the end of fiscal year 1966, transfer of the Bureau's Washington laboratories to a new ultra modern complex at Gaithersburg, Maryland was about half completed. The new laboratories will enable the Bureau to plan and conduct a more effective program consistent with its increasing responsibilities. In recent years the explosive growth of science and technology has brought urgent demands for new and more accurate standards, better measurement methods, and greater availability of data on materials properties. Yet for some time the Bureau's research and service activities have been hampered by inadequate and outmoded laboratories at the Washington site.

The Gaithersburg move provides the Bureau staff with one of the most modern research installations in the world, its buildings designed for convenience for scientific work, flexibility in space arrangements, and adaptability to further expansion when necessary. The 565-acre site contains adequate space for further construction, as well as for location of buildings that need to be relatively isolated, such as a reactor building. In addition, the rural location removes the Bureau's work from the variety of mechanical, electrical, and atmospheric disturbances present in a city and reduces the effects of these factors on precise scientific measurements. A further advantage of such a location is that



Airview of the new NBS site at Gaithersburg, Md., shows the 15 major buildings that have been constructed on the 565-acre site.

scientific experiments can be conducted with a minimum of interference to and from neighbors.

History

The National Bureau of Standards emerged from World War II with outmoded and overcrowded facilities. Many of the staff were in temporary quarters, some of which had been erected as temporaries in World War I and added to in the second war. Furthermore, no technical operating division was completely housed in a single building. (At the time of the move to Gaithersburg, one had become scattered in 17 different buildings and the median spread was 6.) Efforts to secure funds to improve the laboratories and to consolidate activities were largely unsuccessful, although limited funds were made available to do some overhauling of the greatly overloaded electrical distribution system. The first significant relief came in 1950 when the Congress provided funds for a new laboratory for the Bureau's radio work. The Congress stipulated, however, that the laboratory must be out of the Washington area. Boulder, Colorado was selected as the site for this laboratory which was dedicated in 1954.

The opportunity to acquire new facilities began to emerge in 1955 as part of a dispersal program by the Executive Branch of the Federal Government. The National Bureau of Standards was selected as an agency that did not need to be in the City of Washington, and the Bureau was queried as to its interest in

relocation. Since this appeared as a chance to acquire the badly needed new laboratories as well as to acquire certain facilities which could not be accommodated on the old site, the offer was readily accepted. Relocation meant, however, that the old site, which had been in use since 1903, would have to be given up. Inasmuch as the Bureau's original site had been selected to provide a rural location and the city had subsequently completely surrounded it, the prospect of a new rural site had a special appeal.

Site Selection

In order to meet the dispersal criteria the relocation site had to be at least 20 miles from the center of Washington and could not be on the Washington-Baltimore Corridor. In addition, NBS management imposed the following requirements: (1) The site should be reasonably accessible by automobile from the homes of the majority of the Bureau's senior professional staff. (This limitation stemmed from the fact that a seriously high percentage of the senior radio staff was lost in the move to Boulder, Colorado, two years earlier.) (2) The site should be near to high-speed roads for the ready access to the center of Washington and its airports. (3) The site should contain at least 400 acres (the old site had 67 acres) in order to provide buffering from potential neighbors as well as to allow for expansion. (4) The terrain should be relatively flat and high. (5) Utilities (water, sewer, electrical power, gas) should be reasonably accessible.

A task group consisting of NBS and Public Building Service employees considered nearly 100 locations and narrowed the list to about five for detailed examination by the Bureau's management. The site finally selected met all of the requirements. It contained 565 acres of high, nearly flat terrain, it was near the Gaithersburg interchange of the interstate limited access highway serving northwest Washington, and it was exactly 20 miles from the center of Washington. Most difficulty was encountered in meeting the distance limitation and at the same time the requirement for accessibility to the homes of the senior staff. Large-scale maps were used to plot the residences of staff members. This showed the center of gravity for the homes for the total staff to be almost exactly on the spot of the Bureau's Connecticut Avenue site in Washington, whereas the center for the senior professional staff was at the Maryland-District of Columbia boundary on Connecticut Avenue (Chevy Chase Circle). This pointed to the Northwest as the direction for meeting the 20 mile requirement.

The new site was acquired in July 1956 promptly after appropriated funds became available for its purchase. The Congress

also provided funds for the preliminary planning of the laboratory buildings.

Laboratory Planning

The first step in the laboratory planning was to engage an architectural firm in cooperation with the Public Building Service, which was to have general cognizance over the design and construction. Major qualifications required of the architects were experience in the design of modern laboratories, sound engineering competence and a reputation for innovation.

The architectural firm of Smith, Haines, Lundberg, and Waehler, then known as Voorhees, Walker, Smith and Smith, was selected for the preliminary planning. This firm had designed and built some 10 million square feet of research laboratory space in the period following World War II, including laboratories for many of the larger industrial firms, such as DuPont, General Electric, Ford, IBM, and Bell Telephone Laboratories.

In order to provide a reasonable involvement of the employees in the planning of the new facilities, a Laboratories Planning Committee was established comprised of several of the most capable younger scientists of the Bureau. It was the purpose of this Committee to establish some of the more important criteria upon which the final plans were to be based.

The recommendations of the Committee were made available to the architects and virtually all were incorporated in the planning. The Committee remained in existence throughout the design and construction period to consider special problems on which management has needed advice. In addition, an interference "czar" was named whose job it was to investigate and resolve questions arising during the planning relating to interference caused by laboratory sources of noise, vibration, or radiation. Combatting interference and working toward compatibility were not restricted to the planning stage, of course; these activities require a continuing effort.

The concept of a general plan for the Gaithersburg facilities did not evolve in a simple, straightforward fashion. There was backtracking, retracing of steps, and reconsideration of ideas once considered and discarded.

During the early planning certain general criteria were evolved which were used as guides toward a final design. These were:

(a) The needs of working scientists were to be of primary consideration.

(b) Flexibility was essential in order to be able to accommodate to change. This meant that provision should be made for expansion, for rearrangement of space and distribution of utilities and services.

(c) Services and facilities to be shared by most of the staff should be centrally located or distributed. There should be generous provision for library, meeting and conference space, instrument shops, storerooms and dining space.

(d) General space arrangement should tend to group together similar types of work to facilitate communication, but arrangements based solely on an organizational structure should be avoided.

(e) Since transportation to and from the site would be mainly by private car there should be ample parking space located as conveniently as practicable to the laboratories and offices.

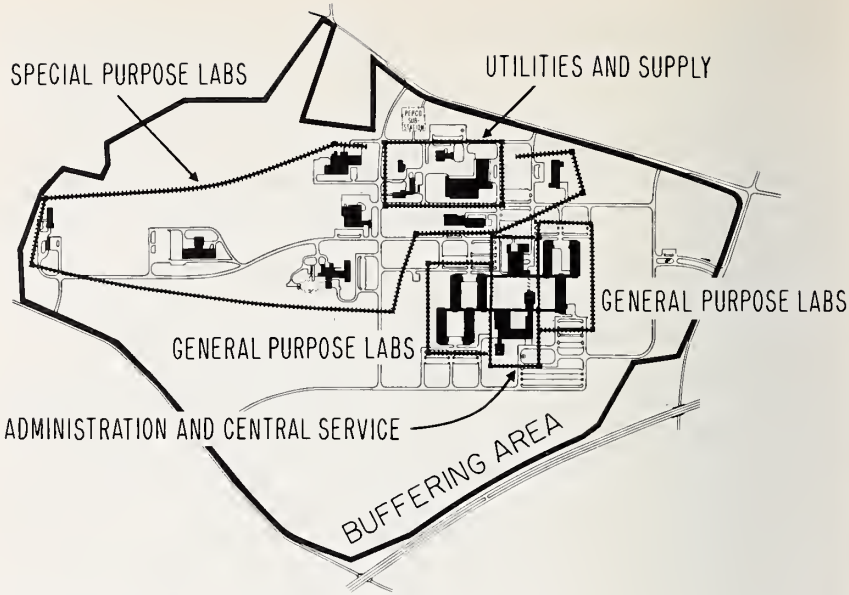
The initial estimates of cost had been made by the General Services Administration in support of the first NBS request for funds. This estimate referred to "a monolithic block-type structure" of a little more than one million assignable square feet to accommodate a projected staff of 3,000 employees. A level of approximately one million square feet of working space remained as a goal throughout the planning. This represented an expansion of about 25 percent over the space available at the Washington site.

Final Design

After the architects had worked for several months with most of the supervisors and senior staff of NBS to ascertain their needs, the architects concluded that the Bureau's requirements could not be accommodated in a single structure. They suggested that detailed planning be on the basis of a multistructure design. The General Services Administration, National Bureau of Standards, and the Bureau of the Budget considered the architects' study and accepted their recommendation.

In substance, this recommendation advised placing all the office and laboratory operations that were reasonably compatible into a single central structure, and segregating in separate buildings those operations that required isolation for any of a number of reasons. Included in the latter were a Radiation Physics Laboratory, Nuclear Reactor, Engineering Mechanics Laboratory, Boiler Plant, Hazardous Chemical Laboratory, Industrial Engineering Building, Acoustics Laboratory, Concreting Materials Building, Fluid Mechanics Laboratory, and Non-Magnetic Laboratory.

This still left most of the scientific work of the Bureau, the Director's offices, most of the administrative divisions, and the Shops Division to be placed in a single building. The architects studied various schemes and finally concluded that a single building to accommodate all of these people and activities would be exceedingly big and cumbersome and would not lend itself well



General site plan of the new NBS Gaithersburg facility.

to future expansion. They then evolved a scheme of a central administration building housing most of the Bureau's nonlaboratory staff, the meeting and dining facilities, and the library, this building to be surrounded by a number of "general purpose laboratories" and instrument shops building.

The office wing was planned to be higher than the laboratory buildings in order to reduce the horizontal distances between the laboratories and the centrally shared facilities. This also made for some resultant economies in construction, as well as providing an interesting architectural feature for the site. The meeting facilities are designed to accommodate scientific meetings of moderate size. There is an auditorium seating 800, a smaller one seating 300, three lecture rooms seating 100, one each for 50 and 25 people, and two seating 12. This area permits concurrent meetings of varying sizes, as, for instance, a symposium in which several simultaneous meetings can be held. Adjoining the meeting area is the dining area which includes a staff lounge, also useful for informal meetings with visitors attending meetings at NBS; a cafeteria seating 650; and three smaller dining rooms which can be reserved for luncheons by groups of scientists.

The library is a section of the Administration Building consisting of a two-story-plus-basement wing at the back of the high section. At present it accommodates 126,000 volumes and is designed to provide expansion to some 200,000 volumes.

Located in the west wing of the Administration Building, the new NBS library contains 126,000 volumes. The spiral staircase leads to the 2d floor gallery of the library.

Adjacent to the library are a small museum and a standards vault. In the vault, behind security glass, are displayed the Nation's standards of physical measurement, or—where space limitations do not permit the entire standard—a symbolic part, such as the "oven" of the cesium beam atomic clock.

The fully enclosed corridors interconnecting the seven general purpose laboratory buildings, the Shops Building, and the Administration Building are intended to make this group of buildings operate as a single structure. However, each of the buildings has its own separate area for staff and visitor parking. A system of roads and streets has been established providing access to buildings and parking areas, and connecting with strategic exits to surrounding state and county roads.

All mechanical and electrical utilities are furnished via underground conduit and pipe systems. Electrical power to all buildings is fed from a site substation owned and maintained by the Potomac Electric Power Company.

General Purpose Laboratories

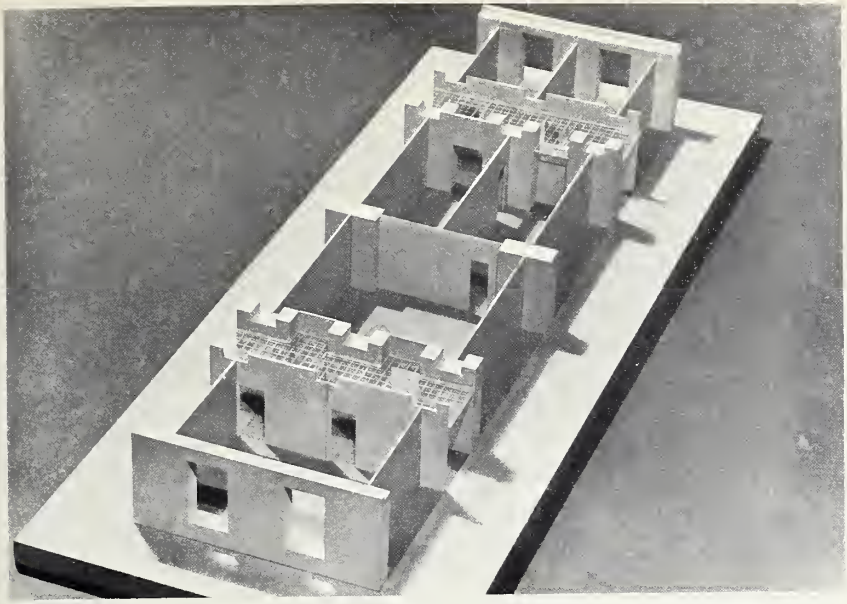
The central complex contains two-thirds of all the space planned for occupancy at Gaithersburg and it has been designed as space suitable for most of the technical operations of the Bureau.

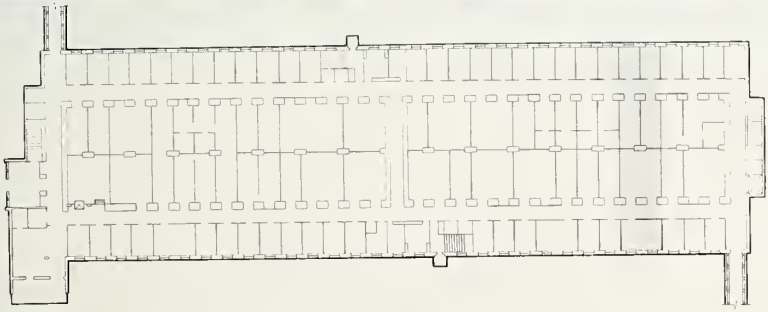
The seven laboratory buildings came to be referred to as the General Purpose Laboratory Buildings because they were designed for flexibility and with the thought that most of the Bureau's laboratory functions could be carried out in such space. Their construction is of the modular type.

The basic module is 11 ft $\times$ 24 ft. Its size will, in general, accommodate one scientist and one assistant. There was little problem in settling the length of the module but the width problem provoked much argument. The architects recommended a 10-ft width, the Laboratory Planning Committee, 12 ft. The latter recommendation was based on the greater ease it provided for accommodating "island" type setups where equipment is in the center of a room with working space on all sides, in contrast to the more traditional arrangement with work benches against one or more walls. An analysis was attempted to try to determine which width would provide optimum space utilization. This was based on the concept that where work actually required a space greater than one module, and therefore must be assigned two modules, the space in excess of the actual need would be "waste space." The analysis showed no clear optimum but tended to favor 11 ft, and this value was selected.

Partly for economy reasons and partly for ease in controlling the environment it was decided that the main laboratories would be windowless with a double row of modules in the center of each laboratory building. A survey of space at the old site showed that in a high percentage of rooms the windows had been covered to provide either optical, thermal or electrical shielding. The final plan makes such improvisation unnecessary. Corridors are adjacent to each laboratory module and on the outside of the corridors are office modules which also can have limited use as laboratories. The office modules are 16-ft long. Services are distributed in vertical shafts in each laboratory module. When a laboratory service is needed in "office" space it can be transferred through the corridor ceiling.

Approximately 35 percent of the laboratory modules have been assigned for use as single units, about 40 percent as double units and remainder in larger increments. There are also L, T, and U shaped arrangements of the modules. Nearly 10 percent of laboratory modules have been assigned for nonlaboratory use such as conference rooms and special offices.





TOP: Cross-section model of a general purpose laboratory with outer and inner rooms separated by two corridors running the length of the building. Offices are in outer rooms and usually paired with laboratories across the hall. BOTTOM: Floor plan of a typical general purpose laboratory.

On the office or exterior side of the corridors approximately 80 percent of the space has been assigned for single module use and most of the remainder for double module use. About 20 percent of the exterior modules are being used as laboratories.

The floors are designed for 150 pounds per square foot. The standard floor covering is vinyl asbestos tile. The ceilings in the offices are acoustical tile and in the labs the ceilings are concrete, painted white. Inserts were provided in the laboratory ceilings for suspending various items of laboratory equipment.

The architects had recommended movable metal partitions from the outset. It was the belief of many at the Bureau that masonry partitions were better for laboratory installations but

after much discussion and studies of experiences of others who had used metal partitions the architects' recommendation was accepted.

The light level was set at 65 foot candles. Some lighting groups recommend a higher level of illumination, but the Bureau's own lighting experts concluded that the difference between 65 foot candles and 100 foot candles was not really worth the additional cost in electrical power or in the additional air conditioning that would be required. Fluorescent lighting was established as the standard, although in some laboratories incandescent was required for technical reasons.

A great deal of thought was given to the problems which can be created in some laboratory environments by electromagnetic interference from fluorescent fixtures. The problem was referred to an Electrical Interference Abatement Committee and that committee extended its considerations to a number of other possible sources of interference and made many valuable recommendations in the course of the planning. One recommendation, for example, was that all electrical wiring be encased in steel conduit, rather than in aluminum conduit because the aluminum would provide no protection against the magnetic fields which would otherwise surround electrical wiring. Another recommendation led to the isolation of all lighting power circuits from the laboratory power. The Electrical Interference Abatement Committee subsequently was enlarged to consider other matters of possible interference, such as sources of noise, vibration, and atomic radiations, and their advice has been invaluable in reducing possibilities of such interferences within the general purpose laboratory buildings. The committee advised, for example, that all sources of noise and vibration connected with building mechanical systems should be kept out of the buildings to the greatest extent possible and those that must be located within the building were to be isolated from the structure. As a result of this recommendation, no reciprocating machinery is permitted in the general purpose laboratories and the building transformers needed for electrical supplies and the fans for distributing air have been provided with carefully and individually designed noise and vibration isolation mounts to minimize the transmission of noise and vibration to the building itself.

The location of air conditioning and other mechanical equipment was given much study. It was finally concluded that since ground floor or basement space was the most sought-after laboratory space, the mechanical equipment would definitely not be there but as far away as possible, namely the attic. For services, the architects recommended horizontal distribution through the

One of the 11 × 24 ft laboratory modules in the general purpose laboratories.

service attic with lines being dropped vertically through service enclosures at every module.

The services actually selected for distribution were those recommended by the Laboratory Planning Committee. They include the following:

(1) cold water
(2) hot water
(3) laboratory waste drain
(4) chilled water (42 °F—for heat exchange)
(5) burner gas—(3″ —5″ W.G.)
(6) compressed air (—15 psi)
(7) vacuum (—20″ —22″ Hg)
(8) steam (15 psi)
(9) 120V, a-c power (single phase 15 A duplex)
(10) 208V a-c power (single phase 15 A)
(11) 208V a-c power (3 phase-20 A—3 wire)
(12) standard frequencies
(13) telephone

It was determined that the laboratories and offices would be air conditioned and year-round control levels were set at 75 °F ± 2 °F, with humidity not to exceed 50 percent. Many of the laboratories, however, required different ambient conditions and had to be specifically designed.

The architects recommended that the general purpose labora-

tories be three stories in height. A single story laboratory building would require a great deal of land space and would be spread out so much that communications between employees would be impaired. Conversely, in multistory buildings the space required to enclose the air ducts associated with the exhausts from ventilating hoods becomes progressively greater with each additional story in height. The architects concluded that three stories was the maximum height for an economical laboratory structure. Four of the seven general purpose laboratories are 3 stories high, the other three are 3 stories plus a basement.

The buildings are themselves modular in that each has 30 interior laboratory modules along each corridor, and each is 105-ft wide and 385-ft long. The site is planned to allow for seven additional general purpose laboratories connected to the central structures. There is a significant amount of highly specialized space in a few of the general purpose laboratories. Among the most interesting are:

Tape Calibration Facility.—This is a room 320-ft long, 11-ft wide, and 8-ft high in the basement of Metrology Laboratory. It was built underground in order to achieve a more constant and uniform distribution of temperature. Further temperature stability is provided by a double wall construction with the cavities filled with insulating materials, and refrigerator-type doors that are at each end of the tunnel.

Photometric Range.—This room is adjacent to the Tape Calibration Facility and is 320-ft long, 12-ft wide, and 10-ft high. In addition there is a 3-ft-square light-tight shaft that runs the full length of the room as a tunnel within a tunnel.

Spectroscopy Area.—In the basement of the Physics Laboratory, structurally isolated from the main part of the building to minimize vibration, is an area approximately 80 ft by 120 ft. This area is subdivided into a number of smaller rooms which will house a variety of types of spectrographs, including a 40 ft Rowland Circle. Coupled to the area is a lightpipe leading to the roof of the building for studies of solar spectra.

Building Research Special Areas.—The general purpose laboratory devoted to building research provides examples of greatest departure from the standard use of modules in other areas. In some areas floors and ceilings have been omitted to provide space three stories in height. In these areas provisions are being made for testing air-conditioning and heating systems, and thermal insulation systems for full-size sections of buildings and specimens of building materials.

Special Purpose Laboratories

Those activities which could not be conveniently housed in a modular type structure are housed in special purpose laboratories. Here the buildings are designed primarily around major pieces of equipment. Three of these have been completed and are now occupied. Four others are under construction and two others are in the design stage.

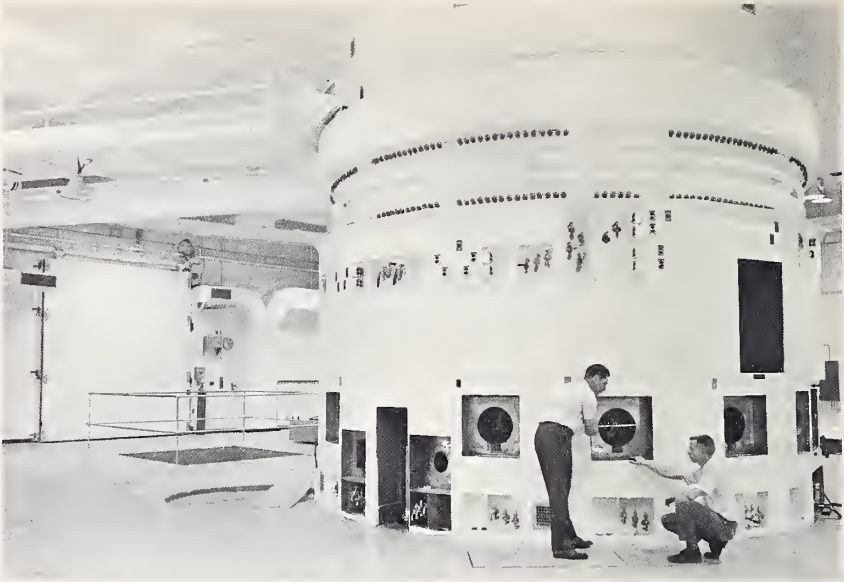
Associated with each of the special purpose laboratories is some general purpose laboratory space. In most of these areas such space follows the same modular concept employed in the general purpose laboratories.

Engineering Mechanics Laboratory.—The first laboratory completed at the Gaithersburg site was the Engineering Mechanics Laboratory which houses the force measuring and force producing equipment. The major feature of the building is a clear 100 ft (approximate) cube which houses a 12 million pound compression-tension testing machine. The machine itself rises 80 ft above the floor and extends into a pit 21 ft below ground. It is capable of supporting horizontal beams up to 90-ft long for flexural tests. In addition, the building houses several deadweight machines, the largest of 1,000,000-pound capacity. This machine permits the Bureau to test force measuring equipment by direct substitution up to 1,000,000-pound values.

Radiation Physics Laboratory.—The Radiation Physics Laboratory is designed to house the Bureau's particle accelerators, the most important of which is a 100 million-volt linear accelerator. This machine, which is called the Linac, has the capability of producing a beam of electrons with energies in the beam of 50 kilowatts—a power output about 100,000 times that previously available at NBS in this energy range. The Linac is almost entirely underground in order to take advantage of earth shielding.

Other accelerators include a 4 MeV Van de Graaff-type machine, a 2-MeV Van de Graaff-type electron type accelerator, a 2 MeV positive ion accelerator, and a 180-MeV synchrotron. This last has not yet been moved from the Washington site but is scheduled for relocation early in 1967.

Nuclear Reactor.—Another special purpose laboratory houses a high flux 10-megawatt nuclear reactor. It utilizes an enriched uranium core, moderated and cooled by heavy water. Thirteen beam ports are provided. The reactor housing can be sealed from the rest of the building which provides supporting laboratory



NBS technicians inspect one of the 13 beam ports of the Bureau's new 10-megawatt nuclear reactor.

space. This latter space is arranged for high level radiation at one end of the building and the low level at the other.

Industrial Engineering Building.—The largest of the special purpose laboratories now under construction is designed to house special processing facilities and furnaces for work on glasses, ceramics, metals, paper and textile.

Acoustics Laboratory.—The Acoustics Laboratory now under construction will house new and larger aneochoic and reverberation chambers than were available to the Bureau on its old site. Each of these chambers is being built as a shell within a shell, the inner shell floating on vibration isolators.

Hazardous Chemical Laboratory.—This building is designed to house work with dangerous chemicals such as high-pressure, long-chain polymers, and the distillation of highly volatile materials. The building is planned so that if an unexpected explosion should occur its effect on the laboratory workers and on other parts of the Bureau will be minimal. It is, of course, located on an isolated portion of the grounds.

Concreting Materials Laboratory.—A special structure is under construction to provide equipment for batching, blending, and storing of aggregates used in connection with the Bureau's studies of structural concrete components and systems.

Fluid Mechanics and Nonmagnetics Laboratories.—Scheduled for construction in the near future are laboratories to house work in fluid dynamics including some special wind tunnel and water tunnel facilities and a laboratory designed with a minimum of magnetic materials.

Scheduling

Construction of the laboratories was planned in four stages in order to speed up the program and to provide contractual packages of sizes which would permit greater competition among contractors with the possibilities of resultant lower prices. It is felt that the overall program was of such magnitude that the number of contractors who could bid on it, had it been let as a single package, would have been very small.

The first phase of construction which began in the summer of 1961 and was completed in the winter of 1963–64, included the initial site development and utilities, a power and air-conditioning plant and the Engineering Mechanics Building. The second construction phase which came along about a year later, consisted of the administration and central services units and the Radiation Physics Laboratory. The third construction phase which was scheduled approximately still another year later, comprised the general purpose laboratories. These were completed in the summer of 1966. The fourth construction phase, which began in the summer of 1966, includes the remaining special purpose laboratories. The construction of the reactor was handled as a separate program and not as a part of the overall activities since it represented a completely new facility.

Moving into the new laboratories was also handled in stages as different portions of the laboratories were completed. The first move took place in the fall of 1963. The major move into the general purpose laboratories took place during the summer of 1966. The moving contracts which included the disconnecting and reconnecting of laboratory equipment were among the largest such contracts ever let in the Washington area.

Costs

The first rough estimates made in 1955 for building, equipping and moving into the new facilities was $63,000,000. This was an estimate made by the Public Building Service on the basis of new floor space alone without any evaluation of specific program requirements. The first appropriation provided by the Congress provided for a more refined estimate of costs based on a study of

actual operating needs. The estimate first provided by the architects was approximately $110,000,000 which by rigorous cutting was scaled down to about $86,000,000. This was the estimate upon which the first construction appropriations were based. Rising costs over the nearly 10-year period that the program has been underway have raised this estimate to about $100,000,000. In addition, facilities not originally envisioned when the relocation plan was approved, such as the Linac and Reactor, have raised the total costs to approximately $118,000,000.

Summary

Although the new laboratories of the National Bureau of Standards will have, when present construction is completed, around 1,200,000 sq ft of working space, the total construction area is approximately 2,300,000 sq ft with an average utilization factor of 52 percent. This factor is low by older standards, but it is a price well worth paying in return for the high degree of flexibility and service mechanization that is provided. The value of flexibility was demonstrated when the major moves into the laboratories began. The laboratories turned over by the contractors were based upon working requirements laid down almost five years earlier. Approximately half of the laboratory space required some modification of space or terminal services before it was occupied. The relative ease with which these changes were accomplished was convincing evidence that flexibility is indispensable. On the other hand, the high degree of mechanization is not without problems. But most such problems are of the shake-down-cruise variety, which will become minimal as experience is acquired in utilizing the new facilities.

CONSTRUCTION TABLE—NBS GAITHERSBURG FACILITY

MAJOR COMPONENTS	PRIME CONTRACTOR	SCHEDULE	
		CONTRACT LET	COMPLETION
SITE ACQUISITION (565 Acres)		—	July 1956
DESIGN & ENGINEERING	Smith, Haines, Lundberg, and Waehler	Dec. 1956	—
CONSTRUCTION			
Phase 1: Engineering Mechanics Laboratory, Power Plant, Initial Site Work	Paul Tishman Co., Inc.	June 1961	Aug. 1963
Phase 2: Radiation Physics Laboratory, Administration and Service Bldgs.	Blake Construction Co., Inc.	June 1962	Aug. 1965
Phase 3: Seven General Purpose Laboratories	J. W. Bateson Co., Inc.	Aug. 1963	Sept. 1966
Phase 4: Special Purpose Laboratories (Sound, Hazards, Industrial, Concreting Materials)	J. W. Bateson Co., Inc.	Apr. 1966	Apr. 1968
Phase 5: Fluid Mechanics, Non-Magnetic Laboratory and Gate House		In Planning Stage	
Reactor	Blount Brothers Corp.	Apr. 1963	Sept. 1966

INSTITUTE FOR BASIC STANDARDS

In support of the general mission of the National Bureau of Standards, the Institute for Basic Standards (IBS) provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce.

This central base consists of a complete, consistent set of units and national standards for physical measurement having precision and accuracy matched to national needs. It is accompanied by a chain of measurement extending to such multiples and submultiples as are needed for continued technological advancement.

PHYSICAL QUANTITIES, NATURAL CONSTANTS, MEASUREMENT SERVICES

The International System of Units (SI), defined by the 11th and 12th General Conferences on Weights and Measures, is the base for the international system of measurement and for most national systems. Six of these SI units—the kilogram, meter, second, degree Kelvin, ampere, and candela—are the arbitrarily chosen values of six quantities of the physical world—mass, length, time, temperature, electric current and luminous intensity. Consistent units for other quantities may be derived from these, with appropriate values fixed by the units selected for the basic six. The English system—pound, inch, second, degree Fahrenheit, etc.—and other systems of units are related to the SI units by definite conversion factors.

At present, the range of items in NBS measurement services covers those quantities known to be of major importance to science and technology. As new developments appear, there will be shifts of emphasis in the Bureau's R&D program aimed at providing measurement, calibration and test services for new quantities, at extending ranges, and at improving accuracies.

The following specific program accomplishments and improved calibration services relating to basic physical quantities and constants were realized in fiscal year 1966:

INTERNATIONAL BASE UNITS

Length

Line Standard Interferometer.—The automatic length-scale interferometer mentioned in the 1965 Technical Highlights has been applied to routine calibration activity with a decrease in calibration fees by a factor of ten. Ultimate accuracy of the instrument has still to be determined, but is at least as great as the method previously used.

Phase Correction Equations.—Decrease in the uncertainty of phase corrections as applied to length measurement has been achieved by the development of equations more adequately relating polarization measurements of surface effects to interferometric measurements of length.

Laser Research.—Previous research and development work has contributed to widespread applications of continuous-wave gas lasers in length metrology. To provide the required knowledge of the laser wavelength in terms of the fundamental standard of length, the wavelength of the 3s–2p4 transition of neon was measured by comparing a helium-neon laser with a standard krypton–86 lamp. However, the gas pressure in the laser discharge tube appears to be an important factor, and this will be studied further. Additional work is under way to measure laser wavelengths in cooperation with the national laboratories in other countries.

Mass

A new mass standardization program at NBS will enable scientists to provide selected scientific, commercial and industrial users with a complete evaluation of their mass-measuring procedures at a tremendous saving of time and money. NBS provides the user with two, one-kilogram (about 2.2 pounds) weights rather than a complete set of test weights that previously took from three to six months to calibrate. Using these two weights as a reference, the user makes his mass measurements and records necessary data (scale readings, relative humidity in the measurement room, etc.), and teletypes this data to NBS. With the aid of a computer the data is analyzed and the results of the measurement are teletyped back to the user. This entire procedure can take place in one hour.

There are advantages of this system to the laboratories, to

NBS, and to the Nation. The analysis provides laboratories with control data to establish and check the precision of their measurement process. Statistical procedures for doing this have been developed and verified at NBS, using many years of mass measurement data. By knowing the capabilities of their system and monitoring its performance on a day-to-day basis, laboratories are in the position of knowing at once when something goes wrong as well as having irrefutable evidence to substantiate the values they arrive at.

Time and Frequency

NBS work in the area of time and frequency includes all aspects of the subject (except for astronomical observations) ranging from basic research on atomic frequency standards to the operation of radio stations for disseminating time and frequency. The four main categories are (1) Atomic Time and Frequency Standards, (2) Atomic Standards Research, (3) Radio Broadcast Services, and (4) Time and Frequency Dissemination Research.

Atomic Frequency Standard.—The present NBS Frequency Standard is the cesium atomic beam standard NBS III, located at the Boulder, Colo., Laboratories. Located close to this standard are some oscillators of high stability whose frequency is compared to the NBS III on a routine basis. The counting of cycles of these oscillators forms the basis of NBS Atomic Time Scale (NBS-A). These standards are disseminated by radio stations WWVB (60 kHz) and WWVL (20 kHz) at Fort Collins, Colo., the high frequency station WWVH at Maui, Hawaii, and the new station at Fort Collins replacing WWV. Frequencies of the Fort Collins transmitters are automatically controlled so that the accuracy of the transmitted signals is essentially that of the NBS III—about one part in 10^{11}. Signals received from WWVB and WWVL at WWV and WWVH are used to correct the frequencies of the latter two stations. Further comparison between these stations and others is accomplished by monitoring, and by carrying portable clocks to other laboratories.

Improved Frequency Standard Studies.—The needs imposed by the tracking of deep space satellites require the development of frequency standards with accuracies at least two orders of magnitude better than the present NBS III. As part of this effort, one hydrogen maser has been constructed and another is being assembled. At present an atomic beam machine is operating with thallium for evaluation as a possible standard. Also, a move is being made to establish a cooperative effort with a commercial firm for the development of an atomic beam machine of improved characteristics.

Time Signals at 20 kHz.—Until recently the 20 kHz signals have been basically standard frequency signals only, and there has been uncertainty whether time information could be conveyed effectively by them because of the narrow antenna bandwidth. However, in the past year a study has shown that signals of this type hold great hope of carrying time information.

Temperature

Copper-Constantan Thermocouple Calibration.—A substantial improvement was made in reporting calibration results for copper-constantan thermocouples (in the range —190 to 300 °C) by using a computer program to reduce data and to print tables with entries at 1 degree intervals.

Manometer Pressure Standard for High-Temperature Gas Thermometry.—A precision manometer constructed for the high-temperature gas thermometry project is unique as a pressure standard. Uncertainties of height, mercury density and gravitational acceleration yield a root-mean-square error of 1 ppm for pressures above 3.5 kN/m^2. The instrument exhibits rapid thermal recovery, thereby allowing the operator to take measurements five times faster than was previously possible. A second important unit developed is a very high quality pressure-transducer which features high vacuum, small volume (33 mm^3), high sensitivity (0.13 mN/m^2), and high stability of the null point. Equality of pressure on opposite sides of the diaphragm is ascertainable to $\pm 10^{-6}$ cm Hg (± 1.3 mN/m^2).

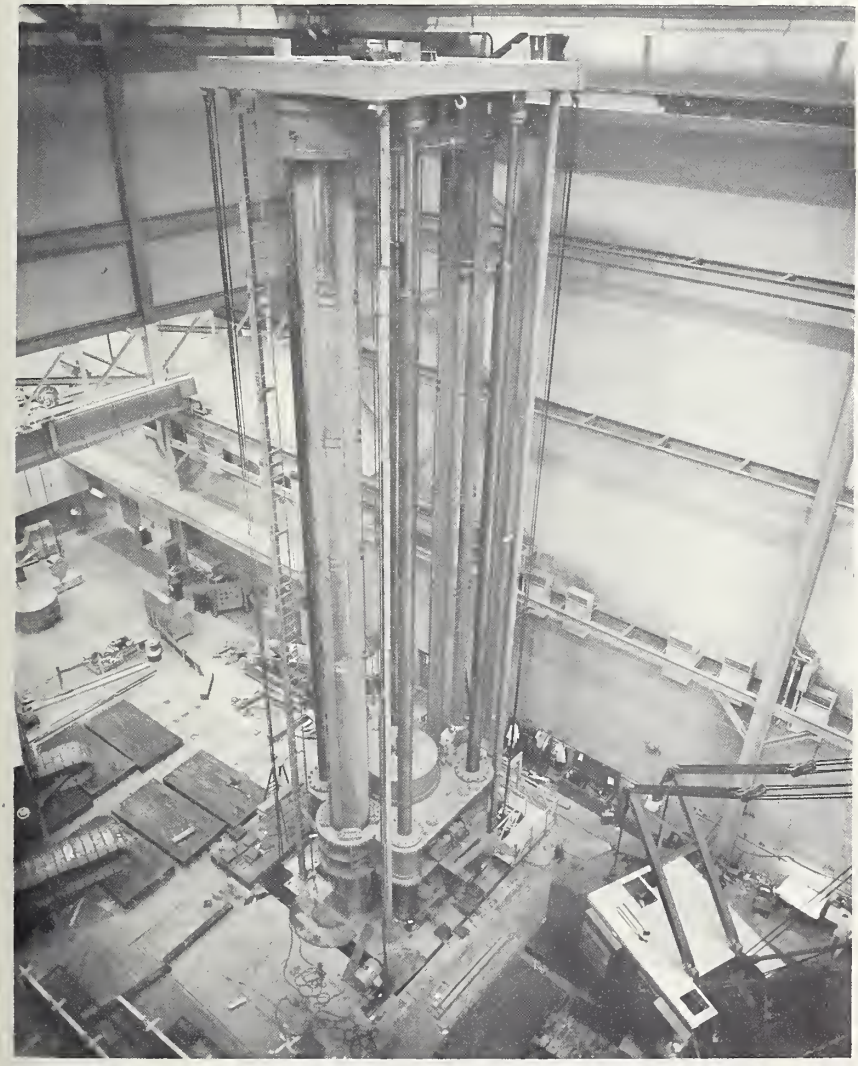
Stability Test for Liquid-in-Glass Thermometers.—Largely based upon work done in the NBS Temperature Section, a stability test for liquid-in-glass thermometers has been written up and adopted for use by the American Society for Testing and Materials. Its use is now under consideration by the International Standards Organization.

Freezing Point of Zinc.—In a cooperative effort with the NBS Office of Standard Reference Materials, thermal analysis was used to establish that high purity (>99.9999 percent) zinc had freezing point ranges of not more than 0.0002 °C at a temperature not more than 0.001 °C from the assigned temperature on the International Practical Temperature Scale (IPTS). While the zinc cell has long been a useful device in realizing IPTS, material of this exceptional purity has never been available. More precise calibration at the zinc point will now be possible.

MECHANICAL QUANTITIES

12-million-pound Force Testing Machine.—A universal testing machine of 12 million pounds capacity has been erected at the

Bureau's Gaithersburg site. This machine provides a unique facility which will be used in calibration of force-measuring devices with capacities up to 12 million lbf (53 million newtons) and in the investigation of the behavior of full-scale structural components such as compression or tension specimens up to 55 feet in length, and beam specimens up to 85 feet in length. It is anticipated that cooperative tests will be undertaken with universities



This twelve-million-lbf capacity hydraulic testing machine, believed to be the world's largest, is being installed in the new NBS Engineering Mechanics Building. A unique facility, the machine will provide the force to calibrate multi-million-lbf capacity force-measuring devices for space and industrial applications and to test full-scale structural components. The machine has a total height of 101 ft, including 21 ft in a pit.

and industry since this machine is the only one in the United States having a capacity greater than 5 million lbf.

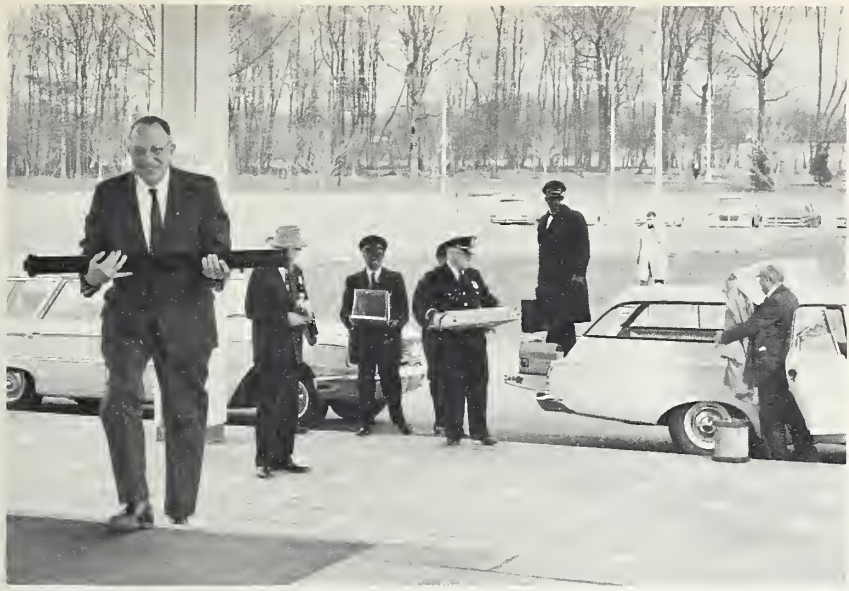
Vacuum Generator.—Installation of a highly stable pressure generator for producing pressures in the vacuum range 10^{-3} to 10^{-8} torr (0.133 to 1.3×10^{-6}N/m^2) has been completed. This facility, utilizing continuous flow of gases through variable conductances, will facilitate the Bureau's work in investigation of vacuum-measuring instruments and in establishing an extended calibration capacity.

High Pressure Reference Points.—In the measurement of high pressures the need for improved accuracy has resulted in greater attention to the establishment of reference pressures, analogous to the fixed points of the temperature scale. New laboratory programs for improved measurement of two such reference pressures have been completed. These are the melting pressure of mercury at 0 °C, in the neighborhood of 108,000 psi (740 MN/m^2) and the crystalline transition pressure of bismuth—the bismuth I-II transition—at 25 °C near 380,000 psi (2.6 GN/m^2). Both of these measurements were made with specially-built dead-weight-loaded free-piston gages. The imprecisions associated with the new measurements are the lowest ever achieved. In the measurement of the bismuth transition, the hydrostatic pressure reached is believed to be the highest yet achieved with a liquid-filled free-piston gage.

ELECTRICAL QUANTITIES—DC AND LOW FREQUENCY

The Volt Standard Moved to Gaithersburg.—The NBS volt standard, consisting of 44 standard cells of the saturated cadmium sulfate type, was moved from its old location in Washington, D. C. to the new Bureau facilities in Gaithersburg, Maryland. The new standard cell laboratory at Gaithersburg includes many features to facilitate research on standard cells and the calibration of cells for the general public, industry, universities, and scientific laboratories. While the old facility in Washington was operated completely on direct current, the new one at Gaithersburg utilizes alternating current and is housed in a shielded room.

Specification for Dry Cells and Batteries.—The ninth edition of the American Standard Specification for Dry Cells and Batteries was prepared and issued. The new edition includes, for the first time, specifications on alkaline manganese dioxide, zinc-silver oxide, and sealed nickel-cadmium cells; previous editions were confined to specifications for Leclanche and mercury cells and batteries. New tests were incorporated to cover cells and batteries for high-rate discharges required in appliances such as tooth-



A. G. McNish, Chief of the NBS Metrology Division, carries a platinum-iridium meter bar, which was the U. S. National Standard of length until 1960, into the administration building at the Bureau's new Gaithersburg (Md.) laboratories. There it was placed in a new standards vault, along with a which is the Nation's standard of mass.
duplicate meter bar and two platinum-iridium one-kilogram weights, one of

brushes, electric shavers, etc., for cells used in electric watches, for cells used in highway safety flashers, and for cells used in electronic photoflashers.

D-C Voltage Divider Calibration.—A simple, easy, and inexpensive technique for calibrating d-c voltage dividers (volt-boxes) to 10ppm has been developed. This modification of a method proposed by the Julie Research Laboratories requires a set of 13 resistors only nominally equal in value, together with a 3-decade resistance box and a microvolt detector to determine their ratios and the ratios of the volt-box under test. All standards laboratories can now extend the range of potentiometric measurements from 1 to 1000 volts, by using the detailed information and error evaluation published by NBS.

Peak AC-DC Comparisons.—Independent verification has been provided of the NBS ac-dc standards on which all a-c measurements of voltage and current depend. A long and careful series of comparisons has demonstrated excellent agreement between a peak ac-dc comparator, developed by the NBS Electronic Instrumentation Section, and the basic rms ac-dc transfer standards of the Bureau. Tests with a wave analyzer preceded by an appropriate fundamental rejection filter showed that at 400 and 1000

Hz the possible waveform error in the comparisons was less than 10 ppm. These results make possible a new calibration service for peak as well as rms ac-dc comparators.

ELECTRICAL QUANTITIES—RADIO

Quantum Electronics.—Calorimeters for the measurement of pulsed laser energy at one wavelength have been built and tested. Two calorimeters of dissimilar geometries have given results which agree within a fraction of a percent. These can also be used for the measurement of power from a CW laser. It is expected that before long these instruments will serve as the basis for an NBS standard of energy, a standard of power, and eventually for standards and calibration services of an increasing range of energy, power, and wavelength.

Frequency Measurements of Laser Light.—A submillimeter-wave laser is being built with the objective of measuring its frequency, and it is hoped that this will be the first step in the long process of making direct frequency measurements of coherent light.

High Frequency Electrical Standards

CW Power Measurement Technique.—An accurate, wide-range, power measurement technique was developed which makes possible the determination of the net power delivered to a load of arbitrary impedance. All power measurements relate to a known arbitrary level by dimensionless ratios which are measured using a precision waveguide-below-cutoff attenuator. At 30 MHz, with power measurements extending from 10^{-2} watts to 10^{-14} watts, the corresponding maximum uncertainties ranged from ± 0.5 percent to 1.5 percent.

RF Current Comparator.—A new technique for measuring the ratio between two sinusoidal currents permits both magnitude and phase to be measured with high precision, and with negligible perturbation of the network. The basic principle involves the insertion of a special network at the point where the current is to be measured. An auxiliary coherent source is adjusted so that the inserted network appears as a short circuit (zero impedance) to the current being measured.

Coaxial Calorimetric RF Power Standard.—A new dual-load calorimetric power meter was developed as a reference standard in the range 2 to 100 W. The maximum uncertainty of the calorimeter is 0.35 percent at frequencies from d-c to 4 GHz.

Pulse Voltage Standard Extended.—The measurement range of the NBS low and medium level pulse voltage standard has been

extended upward to 1000 V, from the former 100 V limit. This standard measures the peak voltage amplitude of pulses with durations as short as 10 nanoseconds. Maximum uncertainty is 0.3 percent; a 1 percent calibration service has therefore been announced. Work is in progress to extend the range downward to 5 mV and upward to 50 kV.

Near-Zone Field Intensity Meter.—Prototypes of two new near-zone field intensity meters were developed and field tested. They were designed to cover only the two ends of the 150 kHz–30 MHz band, but proved to be adequate for the entire band. One resembles a tuned-rf voltmeter, while the other is a heterodyne-type voltmeter with a swept local oscillator. The meters are capable of measuring field strengths of 0.1 to 1000 volts/meter with very little perturbation of the field. This latter property was achieved by building all of the rf circuitry within the antenna or probe and using a specially developed highly resistive transmission line to transmit the d-c output to a remote indicator.

Broad-Band, High Directivity Coaxial Coupler.—A coaxial coupler has been developed for use as a reflectometer in impedance measurements and as a comparator in calibration of rf power meters. The directivity of the coupler is at least 50 dB over octave frequency bands, and auxiliary tuners are not required. The maximum VSWR of the coupler lines is 1.01 up to 4 GHz. More than 40 requests for design information and complete drawings on the coupler have been received from domestic and foreign laboratories and manufacturers.

Improvements in RF Voltage Standards and Measurement Techniques.—The maximum uncertainty in the reference standard bridge used for rf voltage measurement has been reevaluated for frequencies up to 100 MHz and a new figure of 0.3 percent assigned. At 1000 MHz, the new figure is 2 percent. These values for maximum uncertainty were verified experimentally by comparison with power standards. It was also shown that use of the NBS-designed tee-junction allows calibration of voltmeters with a precision no worse than 1 percent in the 500 to 100 MHz frequency range.

Improvements in AC-DC Ratio Measurement.—Improvements in rf voltage bridge measurements over the past few months have given a reproducibility of the ac-dc ratio to ± 0.15 percent at 100 MHz and 1 volt levels. Four different bolometer mounts were used in checking the agreement, in addition to a comparison with power measurements. The mounts included: (1) two negative temperature coefficient thermistors, (2) one negative temperature coefficient thermistor and a "zero" temperature co-

efficient resistor, (3) one positive temperature coefficient thermistor and a "zero" temperature coefficient resistor, and (4) a Bolovac. The resulting measurement uncertainty is estimated to be within ± 0.3 percent, a considerable improvement over the previous value of ± 1 percent.

High Frequency Impedance Standards

Inductive Voltage Dividers.—Inductive voltage dividers having a 2 to 1 ratio of input voltage to output voltage were developed. Deviations from nominal are less than 0.1 ppm from 1 kHz to above 1 MHz, as measured with a limit of uncertainty of ± 0.025 ppm on a bridge specially developed for this purpose. An experimental 1 MHz voltage attenuator having a 42 dB range in 6 dB steps was constructed from seven 2 to 1 voltage ratio transformers. Theoretical considerations and preliminary measurements indicate the uncertainties in attenuation to be less than 0.005 dB per 6 dB step. Also, two seven-decade inductive voltage dividers and several 20-section single-decade dividers were constructed for evaluation from 30 kHz to 100 kHz. Initial checking indicates the presence of systematic errors at 50 kHz of the order of 10 ppm, for which corrections can be made.

Low Impedance Measurement.—Low impedance devices may now be measured accurately with a precision admittance bridge at radio frequency. The technique involves measuring the low impedance in series with a 2-port (three-terminal) impedance which is evaluated as a pi network. By this technique, at 3 MHz, 0.1 mF capacitors have been measured with an uncertainty of about 1 percent, and 0.01 mF capacitors have been measured with an uncertainty of about 0.1 percent. Recently developed precision coaxial connectors and accurate high-frequency capacitance standards are vital to this technique.

RF Capacitance Measurements.—The use of precision coaxial connectors now permits the evaluation of capacitance from 1 to 1000 pF in the 1 to 5 MHz range, with uncertainty limits from about 0.2 to 0.01 percent + 0.002 pF. Preliminary intercomparison between the computed effective capacitance of parallel plate capacitors and coaxial line standards have confirmed these limits.

Electrodynamic Ammeter.—The coaxial radio frequency electrodynamic ammeter developed at NBS operates on the electric motor principle—that of a torque produced on a shorted copper ring by a changing magnetic field. It has a theoretical maximum uncertainty of ± 0.5 percent of rf current for the TEM mode with a high standing-wave ratio.

Improved Calibration Services.—Precision has been improved for all services, with an improvement in overall accuracy in several

cases. Phase shift and time-delay services are now offered over a wide frequency range using existing equipment. Coaxial frequency calibrations have been extended to 18 GHz in some cases. New lower prices recently announced have resulted in a considerable increase in demand for calibrations in the area of power, voltage, and especially in attenuation. Immittance calibrations have also increased markedly with the advent of the new precision connectors.

Microwave Standards

International Intercomparisons.—Power standard intercomparisons are being made on a "round robin" basis with a circulating set of two standards each from the participating nations: Japan, Hungary, Russia, and the United States.

Low Power Standards.—A new microcalorimeter for the 18.0–26.5 GHz band was built and evaluated, and is now in regular use. Evaluation of a new microcalorimeter for the 26.5–40.0 GHz band is nearing completion.

Attenuation Measurements.—A technique has been implemented to allow measurement of small changes in the dissipative components of insertion loss, providing sensitivity of a few parts in 10^5. The measurement is independent of source amplitude fluctuations, and since it avoids stringent microwave power stability requirements, the associated instrumentation is considerably reduced. A new type of readout device has been developed for rotary vane attenuators. This readout eliminates gear eccentricity errors, and has greatly reduced errors from backlash.

Miniature Precision Coaxial Connectors.—The Bureau is fostering cooperative research in miniature precision coaxial connectors which is leading to an extension of the state-of-the-art. It is hoped that this effort will result in a coordinated development by manufacturers of miniature connectors, so that the resulting concepts and devices will be suitable for standardization.

Microwave Calibrations

Power Calibration System.—A microwave power calibration system was developed for the measurement of low-level CW power in coaxial-terminated power meters operating at a frequency of 9.0 GHz. This service makes use of an existing microwave power calibration system for WR90 waveguide and takes into account the errors resulting from the coaxial-to-waveguide transition. A microwave power calibration system was developed for the measurement of low-level CW power in WR187 waveguide (3.95–5.85 GHz) utilizing the impedance variation method of power measurement.

Frequency Calibration System.—A microwave frequency calibration system was developed for the measurement of frequency resonance in cavity wavemeters in WR12 waveguide (60–90 GHz). A calibration system was also developed for measurement of the FM components in the power spectrum of precision signal sources having nominal frequencies of 1.0, 2.5, 5.0, and 10 MHz. The system measures the magnitude of spectral lines relative to the power of the carrier frequency of the signal.

Reflection Coefficient Measurements.—A microwave calibration system was developed for the measurement of reflection coefficient magnitude in WR187 waveguide (3.95–5.85 GHz) using the reflectometer method of measurement. Waveguide interlaboratory standards having reflection coefficient magnitudes from 0.024 to 0.2 in this waveguide size can be determined.

Attenuation Calibration System.—A microwave attenuation calibration system was developed for the measurement in WR430 waveguide (1.70–2.60 GHz) of attenuation difference in variable attenuators, and insertion loss in fixed waveguide attenuators. The IF-substitution method of attenuation measurement is used, and the accuracy of measurement is reported as ± 0.1 dB or ± 1 percent (whichever is greater) for variable attenuators, and ± 0.2 dB or ± 1 percent, for fixed attenuators.

PHOTOMETRIC AND RADIOMETRIC QUANTITIES

Color-Temperature Measurements.—A high-precision photoelectric color-temperature comparator for incandescent lamps has been developed. It generates pulses of red and blue light by alternately positioning two colored filters on a rapidly rotating disk in front of a photo-multiplier tube. The red-blue ratio indications of the instrument are sufficiently sensitive that color-temperature comparisons of test and standard lamps can be made to a precision of 1 °K. This precision is an order of magnitude better than that obtained in visual comparisons.

Optical Wedge Error Calculated.—Optical wedges—filters having a linear variation in optical density along their length—are calibrated for use as density standards. The method of measurement used in calibration introduces a small but previously unquantified error. On the basis of rigorous mathematical analysis, a computer was programmed to calculate wedge corrections which could be applied to measured densities to find the density at the center of the slit. Such wedges can be measured and specified more accurately, and the method can now be included in the "USA Standard Methods for Measuring Optical Density."

Photoionization Studies.—Absolute actinometry in photoionization studies is now possible as a result of the development of special techniques. This advance is based on the results of studies which show that saturation currents can be measured, given proper cell design and suitable choice of parameter such as pressure, light intensity, and monochromaticity. Photoionization studies provide more accurate kinetic information on ion-molecule reactions than conventional high-energy radiation systems, because with monochromatic light of a selected wavelength, a few well characterized ions can be produced in the reaction mixture. This can be coupled with ionization efficiency measurements to provide quantitative information on the number of neutral excited molecules produced.

Detector Standard for the Vacuum Ultraviolet.—A highly successful comparison of two absolute radiant flux detectors has been accomplished in the spectral region 500 to 1000 Å (50 to 100 nm). One is a thermopile, calibrated in the visible, whose blackness, photoelectric energy loss, and surface variation in sensitivity have all been taken into account; the other is a rare-gas ionization counter, constructed and operated to insure that each absorbed photon creates one and only one electron-ion pair. At several wavelengths in this region these two detectors have been compared; results show an agreement of a few tenths of a percent, and a standard deviation of repeatability on the order of 2 percent. This represents an important improvement in the reliability of calibrations for this spectral region. Additional comparisons utilizing other absolute calibration techniques are planned before a detector calibration service is established.

THERMAL QUANTITIES

Calorimeter for Heat Capacity and Enthalpy Measurements.—Taking cognizance of the increased importance of high temperature processes in both industry and defense, a calorimeter has been developed for measurements of heat capacity and enthalpy at temperatures between 900 and 2500 °C. It is believed that this calorimeter is the most accurate in its temperature range. Measurements have been made on pure aluminum oxide up to 2500 °C (200° above its melting point); this substance serves as a heat capacity standard throughout the world. Similar measurements have been made on pure tungsten. This substance will serve as a standard for heat capacity at the highest temperatures and the results will also be used for interpreting the measurements on liquid Al_2O_3.

Radioactivity Standards Developments.—In fiscal year 1966, 505 radioactivity standards were sold and 46 calibrations were performed. One new radioactivity standard, cerium-praseodymium–144 in the form of a β^- solution standard, was developed, and two new tests were established: strontium–89 for the $2\pi\beta$ ionization chamber, and tin–113–indium–113m for the $4\pi\gamma$ ionization chamber. Gamma-ray solution standards of radium–226 were resissued with an overall uncertainty of only 0.5 percent. Investigations were made of the zirconium-niobium decay-scheme parameters, and of the number of emitted 145–keV gamma rays per disintegration of cerium–141. Also, a new accurate method for calibration of gamma-emission rate by peak efficiencies was proposed.

X-ray and Gamma-ray Standards.—A calorimeter for measuring the total power output of gamma-ray sources was completed, and will be used to improve the accuracy of exposure measurements with cavity ionization chambers. Studies were made of the effect of humidity on ionization in free-air and air-filled cavity chambers; the correction previously applied was shown to be incorrect.

Improved Facilities for Calibrating Laboratory Standards.—Concurrent with the move to the new site, facilities for calibrating instruments used as laboratory standards have been greatly improved, modernized and expanded, and now provide an accuracy better than 2 percent. New facilities for the calibration of radium and other small radioactive sources have been installed and calibrations were carried out for 20 radium sources, 19 cobalt–60 sources, and three cesium–137 ranges. Five different types of radiation instruments were given evaluation tests.

Organic Dye Dosimetry Systems.—Organic dye systems, previously used at 10^5 to 10^8 rads in the form of thin films and gel blocks for dose distribution studies, have now been developed for the 10^2 to 10^5 rad range, using the liquid phase. The liquid may also be used to impregnate paper for use as a "go—no-go" indicator in a number of steps from 10^5 to 10^8 rads.

Radiographic Emulsions Response Improved.—The response of radiographic emulsion has been enhanced by the use of monochromatic light exposures before development, and by developing selectively the internal portion of the silver halide grains. Investigations have shown that the enhancement results primarily from a large increase in developed grain size.

Lithium Fluoride Thermoluminescence Dosimetry.—The total

thermoluminescence light emission of lithium fluoride was studied as a function of exposure and exposure rate, and as a function of photon energy. Cobalt–60 gamma rays and a broad spectrum of low-energy bremsstrahlung were employed. No rate dependence of the response was found over the entire range investigated, but the shape of the response-exposure curve was shown to change with photon energy, particularly in the region of superlinearity.

Beam Monitoring Activities.—Construction and assembly of the precision 100 kW Faraday Cup for the NBS linear accelerator was essentially completed, and final assembly of a secondary emission monitor was started. Initial experiments on these devices await the availability of the electron beam in the linac measurement room. Some preliminary experimental work on various current, position, and size monitoring devices was begun using the direct beams from the linac. Position-sensitive signals have been observed in a mock-up nonintercepting pickup.

PHYSICAL PROPERTIES

Explosive growth of the scientific literature and increasing concern with scientific information are well-known national and world-wide phenomena. The Institute for Basic Standards, with its defined emphasis in the quantitative and measurable aspects of scientific information, has certain basic responsibilities to research establishments, to manufacturers and to users for providing reliable and accessible numerical information on the physical properties of substances. These responsibilities are expressed in all phases of the IBS program, including: (1) maintenance and application of measurement standards; (2) definition of physical quantities; (3) calibration services extending to others the capability for compatible measurement; and (4) measurement and dissemination of numerical values for properties which need be determined only once.

The IBS program in this area is very broad in terms of its coverage of the physical sciences. However, it obviously can and does cover only a small portion of the whole field of physical property measurement. The experimental portion of this program parallels the data compilation activities that are described under the National Standard Reference Data System.

The Institute is also engaged in a substantial amount of theoretical investigation. Most of it is aimed at augmenting measurement capabilities by developing methods of calculating physical properties. This is done where the properties are not directly observable or where it is more efficient to establish functional relationships which make it possible to extrapolate measurements

made under one or more sets of standard conditions to a wide range of environments.

The following accomplishments in the specified program areas were realized in fiscal 1966:

Nuclear Properties

$^{16}O(\gamma,p)$ Cross Section Measurement.—An experiment to determine the shape of the $^{16}O(\gamma,p)$ cross section at excitation energies above the giant resonance region is nearing completion. Preliminary analysis of proton energy spectra made at excitation energy intervals of 5 MeV indicate much less high energy structure than in the (γ,n) cross section measured by activation techniques and analyzed by the least structure analysis. Proton energy spectra were measured with large area lithium-compensated silicon radiation detectors developed for this purpose.

Neutron Time-of-Flight Experiments.—Preparations for use of a 45–meter neutron time-of-flight path for photoneutron and neutron experiments with the electron linear accelerator are nearly complete and experimental measurements will start with the availability of a beam in the linac experimental room. These preparations include installation of the evacuated time-of-flight tubes, remotely controlled target changers, and dumping magnets. Computer codes for use in handling neutron time-of-flight data with the linac on-line computer have been written and tested. A study of the folding of resolution functions that occur in neutron time-of-flight experiments has been completed.

Neutron Measurements.—An analysis of the deposition of energy by neutrons in cavities has led to a new and detailed understanding of important instruments used in radiobiological neutron dosimetry. A second study has been completed of the absorption of neutrons by fast neutron reactions in the manganous-sulfate bath method for the absolute calibration of neutron sources.

Linear Accelerator Progress.—The Bureau's 100 MeV linear electron accelerator (linac) produced an electron beam for the first time in July 1965. During the contractor's check-out and demonstration period, which continued until October, it was demonstrated that the energy, energy spread, and beam loading of the accelerator were extremely close to the initial design values. Because work continued on the beam-handling system, very little beam time was possible until March 1966, when a portion of the beam-handling system was removed to install a beam window and dump. This made available a small area for limited experimental work on beam monitoring devices, production of radioactivity samples, induced radioactivity, and multiple neutron production. Irradiations were provided for various users, including

a test of beam windows developed for use with the Stanford two-mile accelerator (SLAC).

Nuclear Orientation Cryostat.—A nuclear orientation cryostat has been completed and installed in the Gaithersburg laboratory. This cryostat uses a dumped liquid helium–3 bath in a closed system to produce a temperature of approximately 0.3 °K, the starting temperature for adiabatic demagnetization of a paramagnetic salt. The magnetizing field is provided by a superconducting solenoid contained within the cryostat. After demagnetizing, the salt is moved into a weaker polarizing field. The radiations from a radioactive source on the surface of the salt are observed with a solid state beta detector contained within the cryostat and external gamma detectors so arranged to observe nuclear spin-beta-gamma angular correlations. The cryostat has been successfully operated with large heat capacity single paramagnetic crystals and developments are progressing so that lower temperatures can be sustained with small heat capacity crystals.

Beta Ray Spectrometer.—A beta ray spectrometer using cooled solid state detectors is under construction. This spectrometer will have good energy resolution with very high detection efficiency for the study of electron energy distribution and electron-electron or electron-gamma angular correlations.

Theory of Nuclear Reactions.—An eigenchannel theory of nuclear reactions has been developed according to which the eigenstates and eigenvalues of the S matrix are directly computed from the shell model. The calculation of all partial and total cross sections is then very simple. In a collective treatment of the giant resonances in spherical nuclei, the influence of surface vibrations on the total photon absorption cross section has been calculated. The agreement with the experimental results in medium nuclei is good. The treatment of the giant quadrupole resonance of deformed nuclei has been extended to include the coupling between different collective modes in a quantum mechanical treatment. This required the development of the quantum hydrodynamics of the nucleus including all modes, viz., the rotations, surface vibrations and giant resonance oscillations.

Residual Radioactivity Studies.—A study of residual activities of materials exposed in linac radiations (both gamma and neutron) was begun. A number of activities not observed with lower energy linacs have been shown to be of major significance with the NBS linac.

Beam Power Handling—A thin (150 mg/cm^2) window for transmission of the electron beam from the vacuum system of the NBS linac and a large water-filled beam dump for absorbing the

full 100 kW beam have been designed and built. These devices have been successfully tested in the direct linac beam at currents up to 600 μA average and power levels up to 60 kW.

The 1.5 MeV Dynamitron.—The 1.5 MeV Dynamitron has been installed and accepted from the manufacturer. Before acceptance, the maximum available power and the characteristics of the voltage and current stability were measured over the voltage range from 0.25 to 1.50 MeV and found to be satisfactory. Further studies on beam size and homogeneity, and on beam handling problems are in progress.

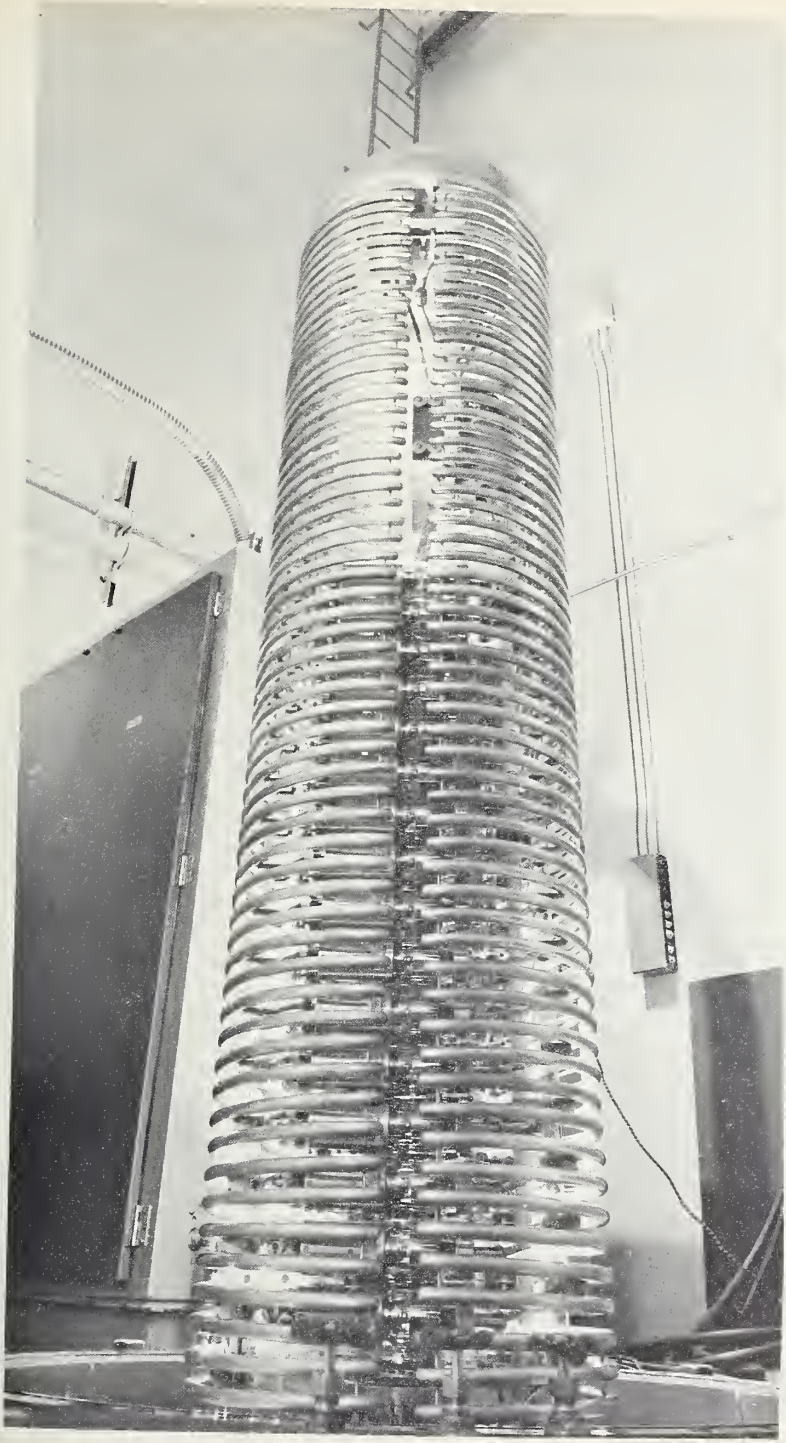
4 MeV Accelerator.—Installation and testing of the new 4 MeV electrostatic accelerator has been completed and experimental programs are underway. Principal features of this machine include a 1 mA 4–MeV direct current output as well as a pulsing capability for electrons. The pulsed beam has a maximum output of $\frac{3}{4}$ A with a repetition rate between 50 and 500 Hz and a fixed pulse width of 1 μsec. The electron beam can be directed into one of two experimental rooms which have a combined area of approximately 1200 square feet. Future plans for improving this accelerator include the installation of a deflection magnet capable of providing high momentum resolution of the electron beam.

Atomic and Molecular Properties

Ion Reaction Rates.—A number of negative ion species, notably oxygen and hydrogen, are important in atmospheric and astrophysical problems because of their capacity for absorbing visible light photons. Current military problems involving the atmosphere have added to this interest. A technique for the study of absorption now has been developed in which the negative ions are illuminated while in thermal equilibrium with the parent gas, at temperatures and pressures characteristic of relevant atmospheric conditions. Preliminary measurements indicate that the earlier results for molecular oxygen ions were correct within a factor of two or three.

Rare Earth Atomic Spectra.—Observations and analyses of ten rare earth spectra were major activities during 1966. Work during the past year has yielded the lowest levels for most of the atomic or ionic species (out of as many as 20,000 lines) being investigated. The results are important for astrophysical research and physical chemistry, as well as for theoretical atomic physics.

Atomic Spectra in the Vacuum Ultraviolet.—A number of atomic spectra have been newly observed in the vacuum ultraviolet, both for analysis and to obtain more accurate wavelength standards in the region 500 to 2000 Å. Several hundred lines



The NBS Radiation Physics Laboratory's 1.5 MeV dynamitron accelerator with its pressure tank removed.

have been measured with wavelength uncertainties less than 0.001 Å, greatly increasing the number of possible secondary standards.

Details of Internal Molecular Motions and Geometry.—High-resolution infrared and microwave techniques have been applied to studies of the fine details of internal molecular motions and molecular geometry. Of particular interest are microwave studies of the transient molecular fragment CF_2 and the high-temperature species CsOH. These represent the first unstable molecular species with more than two atoms which have been detected by microwave techniques. The experiments have shown several unexpected features of the internal vibrations in these molecules which are being investigated further.

Infrared Studies on Refractory Material Vapors.—Infrared measurements on the vapors from refractory materials have been carried out using the matrix isolation technique. In particular, the fluorides and chlorides of magnesium, calcium, strontium, and barium have been investigated in this way. It has been possible to determine the molecular geometry and vibrational frequencies of these molecules, which are important constituents of high-temperature systems but which are extremely difficult to investigate directly.

Laser Action in Molecular Gases.—A program for the study of laser action in molecular gases has made considerable progress. A very detailed series of measurements on the output from a nitrogen laser was carried out and has led to a reasonably good understanding of the mechanism of this system.

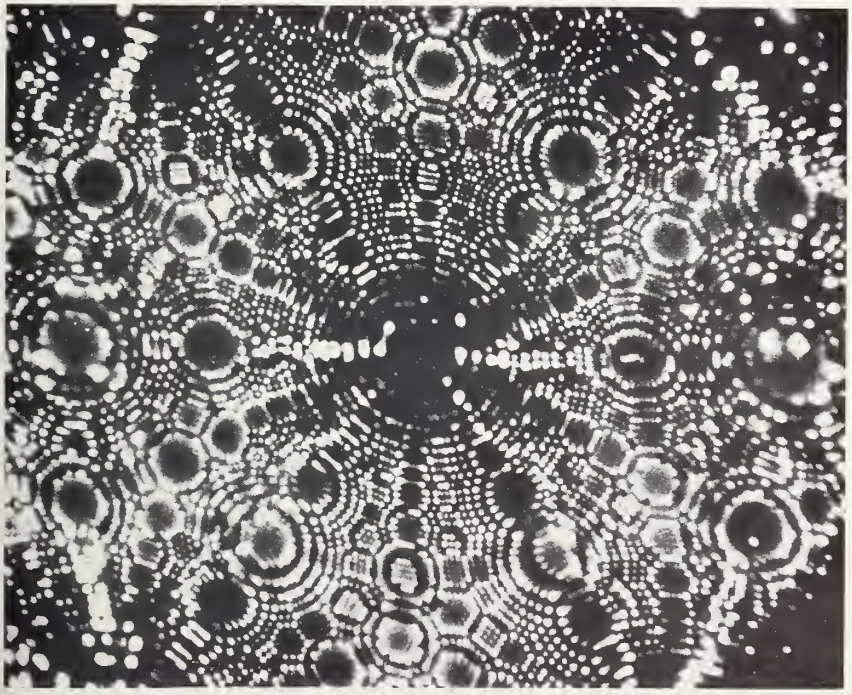
Profiles of Resonances in Atomic Continua.—The photoelectric scanning monochromator has been put to work studying the profiles of resonances found in the photoionization continua of the noble gas atoms. These resonances are due to short-lived discrete high-energy states of atoms involving the excitation of inner electrons or the excitation of two electrons simultaneously. These states interact with the adjacent continua, resulting in resonances which appear as absorption lines superimposed on the continuum, windows in the continuum absorption, or a combination of the two resulting in asymmetric features. Data have now been accumulated on the profiles of the strongest resonances occurring in helium, neon, and argon and work is proceeding with similar measurements in krypton and xenon. Also, a new spectroscopic instrument, a 3–meter grazing-incidence monochromator, was put into operation on the NBS 180 MeV synchroton.

Oscillator Strengths of Molecular Hydrogen.—Oscillator strengths of molecular hydrogen derived from electron scattering

measurements show that the generally accepted optical absorption coefficients in the wavelength range 850 to 1100 Å are in serious error. Further measurements in xenon and krypton have resolved peaks due to inner shell *"d"* electrons. Some of these energy levels had not previously been observed. Other measurements with 20 keV electrons have shown inner shell excitations in aluminium and beryllium, permitting measurements of cross sections for these processes as well as x-ray absorption coefficients. In this very soft~100 eV x-ray region few similar measurements exist.

Electron Scattering From Liquid Alloys.—The unique measurements on electron scattering from liquid metals have been extended to alloys. These measurements, besides showing changes in the band structure of bismuth upon melting, have shown that in indium-bismuth and indium-aluminum alloys the excitation energies change continuously with composition.

Field Emission Energy Distribution Measurements.—The first precision measurements of field emission energy distribution from known perfect single crystal planes of tungsten have been completed. These measurements yield a value for the work function



A micrograph produced in one of the Bureau's field-ion emission studies. The pattern shows a clean surface of tungsten. Atoms appear as bright spots of light.

of the 110 plane of tungsten which is anomalously high. This result is significant in that it cannot be reconciled with the currently accepted theories of electron emission.

Photodetachment of Negative Ions.—The absolute cross section for the photodetachment of electrons from I^- has been redetermined to be about a factor of two larger than the previously accepted value. The difference is ascribed primarily to one systematic error whose absolute limit can now be measured for the first time in the new NBS photodetachment apparatus. The absolute cross section and its variation with wavelength in the threshold region for the photodetachment of electrons from SH^- and SD^- have also been measured. Preliminary analysis of the data indicates no isotope effect in marked contrast to similar experiments with OH^- and OD^- performed recently at NBS.

Plasma Spectroscopy.—The wall-stabilized arc was used to measure a number of transition probabilities in Sulfur II. Measurements were also made of the line broadening in Sulfur II, and the results provided part of the motivation for a re-examination of the theory of Stark broadening for positive ions. Shock tube measurements of some ultraviolet oscillator strengths in Carbon II were also completed; they agree nicely with some recent calculations on Carbon I and II performed at NBS.

High Resolution Bremsstrahlung Measurements.—Investigations of 1 to 4 MeV bremsstrahlung from intermediate and thin targets are in progress. A new experimental tool is the lithium drifted germanium detector, whose high resolution permits careful mapping of the upper end of the x-ray spectrum. Ge detectors ranging from $\frac{1}{4}$ to 10 cm^3 are being used and the total absolute efficiency of the detectors as a function of energy is being measured with NBS radioactivity standards. Emphasis is being placed on absolute calibration of the bremsstrahlung flux density to permit greater accuracy in the measurement of nuclear and atomic cross sections.

Energy Required to Create an Electron-Hole Pair.—The relative energy required to create an electron-hole pair by ionizing radiation, ε, was measured in silicon in the interval from 4.2 to 77 °K. These measurements indicated that ε decreased less than 1 percent in this range. The slight temperature variation of E is in agreement with the predictions of the Schockley theory. Work done elsewhere had indicated that ε was as high at 5.2 eV at 20 °K.

Theory of Thick-Target Bremsstrahlung Production.—The bremsstrahlung emerging from thick targets has been calculated for aluminum and tungsten absorbers with electron energies be-

tween 100 keV and 10 MeV. The dimensions of such thick targets are comparable with the range of the incident electrons, and the multiple scattering of the electrons and bremsstrahlung photons is important. The available theory of bremsstrahlung cross section, when combined with Monte Carlo transport calculations, is adequate to account for the available experimental results.

Energy Transfer.—The intensity distribution of the CH emission spectrum produced in the reaction of oxygen-atoms with acetylene has been studied. The *rotational* energy initially carried by CH is distributed in a highly non-equilibrium fashion and is effectively redistributed to a room-temperature thermal distribution by collisions with inert gases. This rotational energy relaxation process has been interpreted in terms of a "two-state model," one state corresponding to the initial, high-temperature distribution, and the other to room temperature. The efficiency for rotational energy transfer has been deduced.

Spectrum of Helium.—Experimental and theoretical studies on the vacuum ultraviolet emission spectrum of helium have provided information on the transient species He_2. The 600 Å bands, which show structure similar to vibrational transitions, are not due to emission for electronically excited He_2 but come from emission during the collision of an excited and a normal helium atom. The structure is merely a reflection of the nodes and antinodes in the wave-function in the continuum region above an attractive potential well. The spectra permit deductions concerning the shape and depth of the well.

Fluorescence Appearance Energies.—"Fluorescence Appearance Energies" is a new technique in which photons selected by a vacuum monochromator are absorbed by simple molecules (H_2O, N_2O, NO_2) contained in a cell. The fluorescence of fragments is measured normal to the incident beam. The threshold energies for the appearance of the fluorescence due to $OH(A^2\Sigma+)$, $NO\ (A^2\Sigma+)$, $NO\ (B^2\pi)$ have been measured for the first time. The fluorescence yields have been measured over the wavelength interval from the appearance threshold down to the LiF cutoff at 1050 Å. These fluorescence yield measurements, in the case of N_2O photolysis, have also revealed thresholds for the production of $N(^2D)$ and $N_2(B^3\pi g)$.

Matrix Isolation Characterization of Free Radicals.—The thermodynamic properties of NCN have been calculated from the measurement of fundamental vibration frequencies. The carbon nitrogen stretching force constant approaches a value characteristic of a doubly bonded species. The force constants and thermodynamic properties of CNN have been similarly derived.

Measurements on HNF have also led to values for the thermodynamic constants of this radical.

Radio Materials.—Measurement emphasis in this area is on methods of measuring dielectrics at elevated temperatures. The effect of sample shape on spin wave resonances has been studied in polycrystalline materials, and related studies on single crystals are in progress. An apparatus for studying dielectric properties of materials at 2mm wavelength has been completed. Large, highly pure crystals of sodium chloride and calcite have been grown.

Quantum Electronics.—Experimental studies of the Raman and Brillouin effects produced by coherent radiation have continued. Progress has also been made in the redetermination of the fine structure constant by the study of ionized helium, and in the evaluation of an absorption Stark voltmeter.

Radio Plasma.—During the past year work based upon the brush cathode plasma developed at NBS has been completed. Various diagnostic tools have been compared, and their ranges of agreement ascertained. The recombination coefficient of helium was measured. Some new millimeter wave interferometers for diagnosis were built. Considerable experimental and theoretical work upon the noise emission maxima of plasma in a magnetic field (the so-called Landauer effect) was done.

Solid State Properties

The experimental determination of magnetic hyperfine fields is important in understanding the microscopic mechanisms of magnetic behavior. To supplement nuclear magnetic resonance studies of the 4*d* transition metals, a study of the 4*f* transition metals was begun. Europium was selected as the first rare-earth metal to be studied. This element becomes antiferromagnetic at 87 °K and possesses a helical (screw type) spin structure.

Thermodynamic and Transport Properties

Electromotive Force Series for Halides and Oxides.—Electromotive force series for the elements in solid and molten halides and oxides were developed for a number of temperatures from 25 to 3000 °C. In these series the elements are arranged in decreasing order of reducing power, i.e., each element has a positive electrical potential when placed in contact with the element below it in the series. Since these series give the relative stability of elements or metals in solid and molten salts, they have wide utility in interpreting industrial processes, such as electrochemical production of energy, electroplating, or electrorefining. The fluoride,

chloride, bromide, and iodide series cover 69, 96, 90, and 82 elements, respectively.

Membrane Reference Electrodes for Molten Salts.—A potentiometric method utilizing glass membrane reference electrodes was developed for determining the composition of molten salts with respect to cations for which reversible electrodes can be constructed. The method is capable of measuring the concentration of heavy metal ions with an accuracy of 1 percent even in very dilute solution as long as a small amount of sodium ion is present in the melt.

Heat Capacity at Low Temperature.—Measured results were made of the heat capacity of niobium-doped $SrTiO_3$ between 0.03 and 1 °K. Results demonstrated the removal of an anomaly below 0.38 °K by application of magnetic field, thus confirming the superconducting nature of the transition. The "thermodynamic critical field" (calculated from T_c and the γ term from the normal-state specific heat measurements) is in good agreement with that obtained by magnetic moment measurements in specimens of the same carrier concentration.

Transport Properties of Compressed Gases.—The transport properties of dilute gases at pressures around 1 atmosphere are independent of pressure or density. However, when a gas is compressed this is no longer true. Heretofore it was believed that the density dependence of the transport properties of gases could be represented by a power series similar to that of the thermodynamic properties. It was discovered that this is not the case and that actually the transport properties of gases depend logarithmatically on the density. This development should affect significantly the procedures for correlation of experimental data and the prediction of transport properties of compressed gases.

Excitation Energy Transfer.—A new detector was developed for the transfer of excitation energy between identical chromophors. It was used to study the transfer in a system where dipole-dipole coupling between the chromophors is expected to be very small. An anomalously large transfer distance of 45 Å was determined, which cannot be explained by present theories. Measurements were also completed on intramolecular excitation energy transfer on two molecules where the chromophors are at opposite ends of a rigid steroid bridge. These two molecules have the unique property that there is complete energy transfer to the lowest energy state in the singlet system but no energy transfer in the triplet system.

Phase Transition Measurement Technique.—A novel technique

for determining phase transitions has been developed using gas-chromatography to study solid-solid and liquid-liquid transition temperatures. The system to be examined is used as the "liquid phase" placed on the column. The efficiency of the column for gas chromatographic separations is studied as a function of temperature. At the transition temperature the column efficiency changes markedly. To date, the method has been applied to metal salts of stearic acid. The technique may have advantages over differential thermal analysis.

Heats of Solution.—Initial measurements on the heat of solution of THAM (tris-hydroxy methyl aminomethane) in aqueous hydrochloric acid were made with a new adiabatic heat-of-solution calorimeter. THAM has been proposed as a working standard for the evaluation and possible calibration of heat of solution calorimeters. Measurements will be conducted on a more highly purified sample now in preparation. Measurements of the heat of thermal decomposition and solution of silver perchlorate were also made. The results confirmed the values previously obtained for the heats of formation of other alkali metal perchlorates.

Transition Probabilities of Argon.—As an aid in determining accuracy of temperature measurements in the region of 10,000 °K, transition probabilities of 29 lines in the 4s–4*p* array of argon have been determined, in agreement with theory within combined error. Measurements are being planned for this array using the "life-time" method. This will be the first time that two high precision, independent methods have been used to determine the same transition probabilities.

Susceptibility at Very Low Temperatures.—For the region of extremely low temperatures (below 1 °K) the paramagnetic susceptibility of selected substances offers the most generally useful quantity for an indication of temperature. Measurements made on the inorganic salt cerous magnesium nitrate have shown that temperatures as low as 0.002 °K may be produced utilizing this salt as the cryogenic agent. By measuring the temperature dependence of the susceptibility, a thermometric scale for the range 0.002 to 2 °K has been obtained.

Heats of Solution with Rotating Bomb Calorimeter.—A method has been developed for measuring heats of solution of metals in hydrogen fluoride, using a rotating bomb calorimeter and collecting and accounting for the gas evolution. This work forms an important item in the NBS development of fluorine reaction calorimetry, in which fluorine is substituted for oxygen as an oxidizing agent.

Heat Capacity of Superconductors.—Measurement of the heat

capacity of niobium-doped strontium titanate between 0.03 and 1 °K demonstrated the removal of the anomaly appearing below 0.38 °K by application of a magnetic field, thereby confirming the superconducting nature of the transition. The "thermodynamic critical magnetic field" (calculated from the values of the zero-field transition temperature and of the normal-state specific heat) is in good agreement with that obtained by magnetic moment measurements on specimens of the same carrier concentration.

High-Temperature Properties of Argon.—A report was completed on computation of properties of argon in equilibrium with its first and second ions up to 35,000 °K (including corrections for neutral-neutral and ion-neutral particle interactions). The report will be used by the Air Force for reduction of test data and design of advanced hypervelocity test facilities.

Compressibility of BF_3.—Experiments have been completed on compressibility isotherms of gaseous BF_3 to 225 °C. Significant improvements in the constancy of sample volume and the accuracy of pressure measurement above 125 °C were achieved through use of a new capacitance sensor in the transducer, which should permit extension of accurate PVT measurement up to 500 °C. Reproducibility of the transducer null (1 atm) for adverse operating conditions at pressures up to 250 atm and at temperatures from 25 to 225 °C is ± 0.02 mm Hg ($\pm 2.6 \times 10^{-5}$ atm) rather than the ± 0.1 mm Hg previous reported.

Chemical Kinetics

Photochemistry Studies of Excited States of Radicals.—Programs in photochemistry have focused on excited states of radicals. Reactions of CH produced from flash photolysis of methane indicate a method for the evaluation of an absolute reaction rate constant. Studies of the radiolysis of hydrocarbons in the solid, liquid and gaseous state have led to a deeper understanding of radiolytic processes.

Theoretical Studies.—Advances have been made in the calculation of potential surfaces for chemical reaction, in the theory of unimolecular reactions using resonance type models, and in the theory of autocorrelation functions as applied to transport phenomena.

Colloid and Surface Properties

Flash Filament and Field Emission Studies.—Expanded programs in flash filament and field emission have led to elucidation of several aspects of chemisorption, and the program in surface ionization has led to the detection and measurement of negative tungsten ion emission from heated tungsten filaments. This will

lead to accurate values for the electron affinity of tungsten and other metals.

Air Pollution Studies.—Low temperature surface reactions, using techniques developed at NBS, have proved valuable for investigation into problems related to air pollution.

Quantum Mechanical Theory of Reaction Kinetics.—The theory of how a simple molecule decomposes after it has been activated by collision has been extended with the adoption of quantum-mechanical theory of resonance scattering to the problem. The decomposition of an excited or activated molecule is, quantum-mechanically, one of treating overlapping resonance states, these states being located in the dissociation continuum. Expressions for the high pressure rate constant have been developed. It has also been shown that non-exponential decay, i.e., non first-order behavior, is to be expected. This work represents one of the few attempts to establish a quantum-mechanical basis for molecular decomposition processes.

Pyrolysis of Hydrocarbons.—Two studies of pyrolysis of hydrocarbons have been completed. The molecules studied, 2,3–dimethylbutane, 2,2,3–trimethylbutane, 2,2–dimethylpropane, and 2,2,3,3, tetramethylbutane may be considered to be methyl-substituted ethanes. The predominant mode of decomposition at 1000 °K starts with a carbon-carbon bond cleavage in all three cases. The rates of this cleavage have been measured. The activation energies are consistent with other estimates of the C-C bond strength. The statistical factors (preexponential factors) for all substituted ethanes are virtually the same. This has resolved ambiguities in previously reported work and has led to new estimates of combination rates of alkyl free radicals and of the enthalpies and entropies of formation for these radicals.

High Energy Radiation and Photo-Ionization.—Studies of the kinetics of ion molecule reactions in methane, propane, propylene, and several cycloalkanes were made using the gamma radiation from a ^{60}Co source. In addition, a well characterized ion-molecule reaction, that between a hydrogen bearing ion and an olefin (propylene, for example) has been established. This involves transfer of H_2 to the olefin to produce the alkane. Since other processes occur at the same time, isotope tracers are used to establish the ion-molecule reaction. The use of this technique shows great promise in enhancing understanding of the interaction of high energy radiation with organic liquids and solids.

Production of CH by Flash Photolysis.—The species CH was produced by the vacuum ultraviolet flash photolysis of methane and identified by kinetic spectroscopy. The rate constants for

three reactions of CH have been measured; they constitute the first direct measurement of CH rate constants.

Photolysis of Hydrocarbons.—The photolysis of propane was studied from 25 to 320 °C. The chain length was measured and found to be 0.07, 0.54, 2.2 and 7.9 at 25°, 150°, 248° and 320°, respectively. The photolysis of ketene at 1470 Å was found to produce molecular hydrogen and C_2O which may be sufficiently excited to decompose further into carbon atoms and CO. Methylene, generated by ketene photolysis at 3130 Å, was found to abstract hydrogen from isobutane at about 300 °C. This is unequivocal proof of a direct abstraction mechanism by CH_2.

The Kinetics of Desorption.—The kinetics of desorption of the β-nitrogen states chemisorbed on tungsten have been evaluated. Using an isotope mixing technique, the production of $N^{14}N^{15}$ from a mixture of $N^{14}N^{14}$ and $N^{15}N^{15}$ is completely accounted for by desorption from the chemisorbed layer. There are two strongly chemisorbed states designated β_1 and β_2, which desorb by first and complex order respectively. The sticking coefficient of N_2 on tungsten above 1500 °K is about 0.014 and not sensitive to pressure or temperature to 1700 °K.

Chemisorption of Nitric Oxide on Tungsten.—The chemisorption of nitric oxide on polycrystalline tungsten was investigated by flash desorption mass spectroscopy and field emission. Dissociation occurs at elevated temperatures with an activation energy of 47 kcal. The change of average work function for monolayer NO coverage on tungsten is $\Delta\Phi = 1.85$ eV corresponding to an average surface dipole moment of 0.35 debye per NO molecule at full coverage.

Chemisorption of Nitrogen on Rhenium.—The chemisorption of nitrogen on rhenium was followed by pressure changes as nitrogen was adsorbed on a clean polycrystalline rhenium filament. The sticking coefficients at zero coverage were measured as 0.06 and 0.009 at 200 and 300 °K respectively. Tungsten, in contrast, exhibits sticking coefficients for nitrogen that are higher by at least an order of magnitude. Field emission microscope observations of nitrogen on rhenium shows quite clearly that at least two binding states exist. The first of these is weak, little stronger than van der Waal's. It is desorbed almost completely by 125 °K. The second state is strongly bound and desorbs only above 1000 °K. At full coverage it corresponds to less than one nitrogen molecule per 20 surface rhenium atoms.

Adsorption of Carbon Monoxide on Rhenium.—The adsorption of carbon monoxide on rhenium was observed with a field emission microscope. The increase in work function at full coverage is

0.9 electron volts. Surface migration from the α state (the weakly bound chemisorbed state) does not occur because of the dominance of prior desorption. Surface migration from the strongly bound state is characterized by a very diffuse boundary.

Surface Reactions.—Gaseous NiF_2 NiF, and F are the major products formed in the reaction of fluorine with nickel. The rates are linear with fluorine pressure. The rate limiting step in the formation of NiF_2 has an activation energy of 39 kcal/mole and is probably due to dissociation of F_2 on the nickel surface. In the investigation of low temperature surface reactions, it was observed that hydrogen atoms add preferentially to the terminal carbon of α olefins at 90 °K. In propylene, for example, the ratio of terminal to nonterminal addition is about 65 to 1. A very striking isotope effect was found. For deuterium this ratio is about 155 to 1 and for tritium, 190 to 1.

Electron Affinity of Tungsten.—The electron affinity of tungsten was determined by its positive and negative self surface ionization. The positive and negative ions emitted from a heated tungsten surface were determined mass-spectrometrically. The ratio of these values, together with the known values of the average work function—4.55 eV—and the ionization potential of 7.98 V, leads to a value of 0.4 eV for the electron affinity of tungsten. This represents a new and significant method for the measurement of the electron affinity of refractory metal atoms.

Adsorption of Chain Polymers.—A random walk model for describing the shape of long chain polymer molecules has been studied. There is a discontinuous change as a function of the adsorption energy per monomer unit, in the average molecular conformation at a critical value of the adsorption energy. In the case of adsorption at a solution surface, the average fraction of monomer units adsorbed on the surface, the mean distance of an end of an adsorbed molecule from the solution surface, and the mean square end-to-end distance in an adsorbed molecule have been determined. Analogous quantities have been established in the case of adsorption of a chain polymer on the surface of a rod-like molecule. Short-range correlation between monomer units (as caused by fixed bond angles) do not influence qualitative features of adsorption at solution surfaces for the random walk model.

Energy Transfer in the Collision of an Atom with a Crystal.—The quantum mechanical cross section for the inelastic collision of an atom with a crystal has been formulated for a one-dimensional model in which the atom-crystal interaction is of the hard sphere

type and in which the crystal is harmonic. The problem has been reduced to determining the value of determinants of large order.

APPLIED MATHEMATICS

The Institute for Basic Standards conducts a program in applied mathematics and statistics to meet varied needs in the development of new measurement techniques and in the evaluation of the results of measurement. The level of the mathematics involved makes it essential to conduct fundamental mathematical research on a fairly broad scale.

Consulting Services.—Illustrative of areas in which consulting services were provided during the year are

a. Matrices and graphs (matrix inversion, solution of large linear programs, determination of eigenvalues and eigenfunctions, theoretical problems in algebra).

b. Differential and integral equations (ordinary and partial, single equations and systems).

c. Special functions of mathematical physics (properties and relationships, numerical calculations).

d. Design of experiments (selection of statistical techniques, assessment of precision and accuracy, quality control).

e. Statistical analysis (analysis of data, error analysis, statistical computation).

f. General mathematical operations research (e.g., simulation, model-building).

g. Optimization methods, both discrete (network analysis, error-correction codes, etc.) and continuous (linear and nonlinear programming).

Statistical Methods.—Research was conducted in probability and mathematical statistics supporting the work of Bureau staff. Typical theoretical studies were concerned with problems that arise in fitting a straight line with repeat measurements and a "between" component of variance, and also with the properties of the standard deviation, mean deviation, and range for small samples from some nonnormal distributions. A significant contribution to analytic procedures for isotopic analysis resulted from work on the statistical evaluation of uncertainties of reported determinations by isotopic abundance ratios and atomic weights of selected elements by mass spectrometric methods. Experiment designs for calibration work were also developed.

Numerical Solution of One-Dimensional Whisker-Growth Equation.—In collaboration with the NBS Institute for Materials Research, work on the numerical solution of the one-dimensional

whisker-growth equation was completed. The asymptotic results obtained analytically have been numerically confirmed. This work opens the way to determining surface diffusion constants of crystals.

Mathematical Modelling.—Work continued in modelling aspects of the textile industry, and on the analysis of mail sorting systems. As investigation was conducted aimed at developing methods to estimate proper protection levels for various elements of a communications system. Significant theoretical results were obtained on combinatorial methods, in linear and nonlinear programming, and in the development of mathematical models and methods useful in the analysis and synthesis of possible advanced interurban transport systems.

Handbook of Mathematical Functions.—The fourth printing of The Handbook of Mathematical Functions occurred during the year. Corrections were submitted for the fifth printing and plans begun for a second edition. This unique volume of mathematical tables supplemented by useful explanatory text is a Government Printing Office best seller, over 56,000 copies having been sold with no indication of termination in demand.

Laboratory Data Reduction.—The increasing use of computers in scientific and industrial applications presents communication problems to the scientist not familiar with computer programming. Because of widespread interest, NBS has published a handbook entitled "OMNITAB—A Computer Program for Statistical and Numerical Analysis." This provides a general-purpose digital computer program which permits users to communicate with a large computer by means of simple English sentences. Some statistical computations were carried out for Bureau scientists, and preparation of a library of OMNITAB statistical routines was begun.

TECHNICAL ASSISTANCE TO OTHERS

The Institute is a source of technical assistance and consultation to other Government agencies with problems in specialized areas of physical measurement and applied mathematics. Its sponsorship of the National Conference of Standards Laboratories permits joint study of management and operation techniques, and has led to a series of seminars on precision measurement. In cooperation with various technical societies, NBS also conducts conferences and symposia important to wide segments of science and industry.

Studies for Other Agencies

Contamination Survey.—A survey of radioactivity in commercial materials like steel, aluminum, and copper was continued on behalf of the U.S. Atomic Energy Commission, as part of an extensive study of the low-level radioactive contamination of materials used in reagent chemicals and in the construction of nuclear detectors and their shields. Another study for the AEC concerned the electrodeposition of curium by "molecular plating" and from aqueous solutions.

International Comparisons.—For an international comparison of soft x-ray standards, NBS assisted in the preliminary measurements needed and provided the filters required to adjust the quality of the participants' x-ray beams. The Bureau also took part in an international comparison on the determination of the content of ^{90}Sr in rice flour.

Helicopter Blade Lighting.—The helicopter blade-tip lighting system developed for the Navy has been incorporated in helicopters being produced by three American manufacturers.

Propeller Lighting System.—A system for illuminating propeller blades has been developed for the Navy, and should substantially reduce the accidents that occur when crewmen service planes at night. To make the blades visible, a strip of phosphor-impregnated epoxy coating is applied to the front and back surfaces near the tip of each blade. Illumination of the blades with ultraviolet lights mounted on the fuselage creates a warning circle of light when the blade is turning. Plans are under way to fit this system to existing aircraft, and to those being currently produced.

Infrared Reflectance of Frost.—The feasibility of measuring the infrared reflectance of frosts formed from water vapor, carbon dioxide, nitrogen tetroxide, and ammonia has been demonstrated. A newly developed spectrophotometer, with special provisions for forming the frost and preventing its contamination and melting, was used for making reflectance measurements over the range 2 to 22 μm. These studies will be of great value in interpreting the data collected by probes mounted on balloons or space vehicles.

Telescope Quality.—The NBS interferometry group has developed a method for measuring the deformation a wave of light suffers on passing through a telescope. By replacing the telescope's eyepiece with a small glass prism-type shearing interferometer having a camera attachment, a photographic record is obtained. The interferometer can be used with the telescope position as it would be for any desired normal use. Using two

mutually perpendicular photographs, information on the shape of the wavefront at many positions in the field of the telescope can be obtained. The technique was tried out on the Kitt Peak 84-inch reflecting telescope, the world's fifth largest. The shape of the wavefront produced by this telescope was determined at more than 500 points spaced 2.8 inches apart.

Radiation Effects on Glasses.—A study is under way to determine whether the radiations encountered in outer space can affect the lenses of optical instruments carried on spacecraft. Changes of refractive index, following exposure to either gamma rays or electrons, appear large enough to affect the performance of optical systems. Continuation of this work may lead to establishment of the maximum radiation doses various glasses can tolerate without significant change, and development of glasses resistant to the dosages encountered in space.

Holograms for Information Storage.—A study has been initiated to explore the basic principles of holography and its use in information storage and retrieval. A hologram is a photographic record of the interference pattern formed when an essentially undisturbed part of a laser beam is recombined with a second part that has been transmitted by or reflected from an object. Illumination of any portion of the hologram by coherent light from a laser creates an image of the entire recorded object. Thus, if the information on a printed page were recorded on a piece of film, and then part of the film was accidentally destroyed, it would still be possible to recover *all* of the recorded information.

Conferences and Seminars

Standards Laboratories.—A four-day meeting of the National Conference of Standards Laboratories was held at the new NBS Gaithersburg facilities. It featured a discussion of the national measurement system by the Director of IBS; reports of committees on national calibration needs, on performance requirements, and on a round-robin measurement comparison; a survey of measurement standards in ten foreign countries; and the premier showing of the Navy film "Why Calibrate?".

Electromagnetic Measurements and Standards.—NBS Radio Standards Laboratory offered a two-week course to scientists and engineers whose responsibilities included precision measurements, quality control, standards, etc. The course included both theoretical and practical instruction and was attended by more than 150 people.

Millimeter Waves. The NBS Radio Standards Laboratory, the Institute of Electrical and Electronic Engineers, the International Scientific Radio Union, and the University of Colorado

brought together engineers and physicists in a conference on Millimeter Waves and the Far Infrared. Quantum electronic and optical approaches were emphasized, including far infrared spectroscopy and atmospheric propagation.

Precision Electromagnetic Measurements.—A fifth conference in the biennial series on Precision Electromagnetic Measurements, which attracted 450 attendees, was sponsored by the NBS Institute for Basic Standards, the Institute of Electrical and Electronic Engineers, and the U. S. Commission of the International Scientific Radio Union. Its scope included new work on lasers, microwaves, and low frequencies. Some of the 45 foreign visitors discussed their own national measurement systems.

Ionization Potential in a Plasma.—Thirty-four plasma physicists and spectroscopists from the United States and Europe attended a special two-day workshop conference at the Joint Institute for Laboratory Astrophysics (JILA) on "The Lowering of the Ionization Potential and Related Problems of the Equilibrium Plasma." The workshop reviewed the status of some extremely controversial problems currently of great importance in the physics of very hot gases.

Bell Sphere Re-entry.—A meeting was held to discuss a new series of re-entry experiments conducted by Bell Laboratories. The purpose of these experiments was to provide the fundamental physical measurements upon which the study of vehicle re-entry can be based. Several central scientific issues have prevented interpretation of the electromagnetic backscatter from the wake of a body traveling at hypersonic speeds. The nature of these problems and their severity, both from the standpoint of observation and the physical processes, was considered in elaborate detail.

International Astronomical Union Workshop.—During the year the Joint Institute for Laboratory Astrophysics (JILA) was chosen as the site of a week-long work session of an International Astronomical Union subcommittee charged with assessing the requirements of astrophysicists for atomic collision cross section measurements. The panel of worldwide experts, in consultation with JILA staff members, prepared a set of major recommendations for presentation to the Union.

Precision and Accuracy in Measurement and Calibration.—Metrologists from industrial and governmental laboratories met in two seminars which dealt with the concepts of a national measurement system and the need for viewing measurement as a production process. Emphasized were the use of designed experiments in the evaluation of systematic error, the analysis

of propagation of error in a chain of laboratories, and the role of computers in the work of calibration laboratories.

Length.—Two five-day seminars discussed the philosophy of measurement, fundamental interferometry, electromechanical transducer evaluation and calibration, deformation theory, spectral light sources, and lasers. Laboratory work dealt with methodology in the measurement of gage blocks, polygons, surface plates, angle blocks, optical flats, surface finish, spherical and cylindrical diameters, and deformation.

High Frequency and Microwave Noise.—This 4-day seminar dealt with generation and measurement of noise, using both state-of-the-art and classical methods, ranging from high temperatures to cryogenic levels. It included laboratory demonstrations of plasmas as noise sources.

THE NATIONAL STANDARD REFERENCE DATA SYSTEM

The National Standard Reference Data System began in 1963 when the Federal Council for Science and Technology requested NBS to assume responsibility for all Government-wide standard reference data compilation activities. This request took the form of a directive establishing NSRDS as a Federal policy. Under this directive NBS was requested to (1) coordinate existing data compilation and evaluation activities throughout all Government agencies; (2) establish standards of quality for the products to be designated as Standard Reference Data; (3) establish standards of methodology including machine processing; (4) establish other functions as required to ensure compatibility; and (5) operate a National Standard Reference Data Center.

NSRDS is concerned, under these instructions, with the production and dissemination of compilations of critically evaluated data. A primary emphasis of the system is to maximize the utilization of numerical information already reported in the scientific literature, as opposed to new measurements. The program includes collection and evaluation of data from the literature, preparation of critical reviews dealing with the state of quantitative knowledge in a particular technical field, and computation of useful functions derived from Standard Reference Data or used in the interpretation of quantitative experiments.

In order to implement its responsibilities for the National Standard Reference Data program, NBS has established an Office of Standard Reference Data. The Institutes for Basic Standards and Materials Research both make substantial contributions to this program. While data are developed along lines of scientific competency rather than management category. IBS generally develops data dealing with particles of atomic and molecular size while IMR developes data on the bulk properties of materials.

For management purposes the technical area of concern has been divided into seven broad categories: (1) nuclear, (2) atomic and molecular, (3) solid state, (4) thermodynamic and transport,

(5) chemical kinetics, (6) colloid and surface, and (7) mechanical. In each of these areas, efforts are being made to develop a comprehensive, coordinated program of data compilation projects. Existing programs under non-NBS sponsorship are taken into account and priorities are determined by consulation with groups of specialists from the academic world, from Government, and from industry.

During 1966 general activities continued to follow the plan described in NBS publication NSRDS-NBS #1, "National Standard Reference Data System Plan of Operation" (obtainable from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Price 15 cents). Effective working relationships with program offices in other Government agencies were continued and expanded. These relationships cover a wide range of formal and informal functions, including participation in advisory conferences, establishment and monitoring of specialized compilation projects to fill a mission-oriented need, creation of jointly sponsored compilation projects and data centers on topics of mutual interest, and development of communication networks among related data centers and data projects.

Communication and collaboration with privately sponsored and individual data compilation projects advanced during the year. Sources of information on such projects include the response to a questionnaire sent to the entire membership (100,000) of the American Chemical Society, and informal discussions with academic and industry scientists.

Significant progress in NSRDS has been made with the appearance of a substantial volume of compilations of numerical data and related material. These reports, technical notes and other publications have established the usefulness of the program among those in the scientific community who have seen and used its output.

The status of developments in primary areas of activity is described below.

Nuclear Data

Two meetings of the Advisory Panel on Nuclear Data were held, one in October 1965 at the National Bureau of Standards in Washington and a second in January 1966, in New York. The following recommendations were made:

1. Existing gaps in the scope of coverage of nuclear data should be filled by soliciting the aid of interesting individuals. Additional compilations of data are needed for the following:

(a) Primary cosmic data.
(b) Nuclear data in the medium energy region (20 MeV to 1 BeV).

(c) Nuclear data in the resonance region and nuclear level densities.
(d) The few-nucleon area.
(e) Polarization phenomena.
(f) Elementary particle data at energies above 1 BeV.
(g) Certain types of reactor measurements (e.g., resonance integrals, neutron ages, etc.).
(h) Positive bombardment results.

2. Emphasis on the use of automatic computers in the compilation field should continue. Not all compilers make adequate use of computers and those that do use different formats, both input and output. In some instances work is duplicated rather than shared.

3. Expansion of existing compilation groups and establishment of new ones should continue to receive priority.

4. The period of time between the scanning of scientific literature and the publication of an evaluated compilation is too long. Therefore an intermediate step, such as the publication of an annotated bibliography should be considered by all data centers. Appropriate user feedback to the compilation center with regard to the usefulness of such an index is necessary.

5. The use of an author-oriented index system such as one based on key words should be seriously considered.

6. A practical, economic mechanism for obtaining some kind of physical information (individual data points, calibration data, etc.) without the need for resorting to historical publishing processes (handbooks, data sheets, etc.) must be made available in the future.

Atomic and Molecular Data

Under this category, the Office of Standard Reference Data participated in the initiation or expansion of projects in the following areas:

1. Atomic energy levels.
2. Atomic transition probabilities.
3. Microwave spectral tables.
4. Cross sections for electron ionization processes.
5. Atomic and molecular collision process data.
6. Mass spectrometric bibliographic information and data.
7. Infrared spectra.
8. Molecular fundamental vibration frequencies.
9. Ionization and appearance potentials.

Cooperative arrangements for joint support of projects of common interest have been made with the U. S. Atomic Energy

Commission, Department of Defense, Advanced Research Projects Agency, and the American Society for Testing and Materials.

In view of the existing complex network of suppliers and users of molecular spectroscopic data, it has been recognized that NSRDS programs should provide for explicit, well-defined statements of criteria to be applied in compiling and evaluating such data. One set of criteria, covering infrared spectra, has been prepared for the Office of Standard Reference Data by the Coblentz Society Board of Managers, and has been well received by spectroscopists. This approach will be extended in other areas.

Solid State Data

Although no major progress has been possible in expanding compilation activities in the area of solid state data, two programs have been initiated which combine thermodynamics and solid state properties. One is on the compilation of high pressure data and the other is the establishment of a Metals Data Center at NBS. The latter project will compile soft x-ray and nuclear magnetic resonance data, coordinate all metals data compilations currently in effect and, where possible, check it for interval consistency to produce Standard Reference Data on metals and metal systems. It is not the intention of the NBS group to reevaluate the data from existing data centers, but to collate and indicate voids and incompatibility in the data.

Reference Work Prepared by Computer.—NBS is preparing a major scientific reference work using significant new computer techniques. This work, a third edition of Donnays *Crystal Data*, will be produced by tape-controlled photocomposition, and the editing of the tape will be done by computer. The text and data are being keyboarded into punched paper tape, partly from the previous edition, partly from new information. The keyboard also produces a typewritten copy, far less elaborate than the final printed copy; it is proofread and corrections are keyboarded into separate pieces of paper tape.

All data from paper tapes are automatically transcribed on magnetic tape. The magnetic tapes are fed into a general-purpose computer, which first inserts the corrections and then performs a variety of editing tasks. The computer then prepares two alphabetical indexes, one by chemical formula, one by chemical compound name.

Finally, the computer deletes certain keypunched signals which are not wanted in print, and breaks the copy into lines of proper length, inserting spaces between paragraphs, breaking into pages, inserting page headings and page numbers. The output of the computer appears on magnetic tape, which is automatically tran-

scribed to paper tape. The latter drives a photocomposition unit operated by the Government Printing Office.

Thermodynamic and Transport Data

Within this subject category, the Office of Standard Reference Data has now participated in the initiation or expansion of projects in the following areas:

1. Thermodynamic properties of inorganic compounds.
2. Thermodynamic and other physical properties of cryogenic fluids.
3. Thermodynamic properties of aqueous solutions.
4. Thermodynamic properties of monohydric alcohols.
5. PVT properties of selected important gases.
6. Phase relationships in metal-metal oxide systems.
7. Thermodynamic properties of metallic elements and binary systems.
8. Thermodynamic properties of fused salt systems.
9. Diffusion coefficients in metallic systems.
10. Diffusion in oxides, carbides, and nitrides.
11. Diffusion in selected gaseous systems.
12. Diffusion in semiconductors.
13. Thermal conductivity of standard materials.

The thermodynamics field is among the most active in data centers and data compilation activity. Some of the data centers produce "products" used by other data centers as input data within computations or as a means for checking consistency of their data. In some situations, data centers duplicate the search —usually with a different focus of attention—of much of the same literature that other centers search in tracking relevant data. For purposes of economy and efficiency the Office of Standard Reference Data has made considerable progress in establishing arrangements between certain data centers to share common tasks, and to coordinate and complement each others' activities.

Chemical Kinetics Data

A report of the status of the chemical kinetics program was presented on March 30, 1966 to the NAS-NRC Committee on the Kinetics of Chemical Reactions, which is serving as the Advisory Committee to the Office of Standard Reference Data on this program. A series of review monographs on selected topics in chemical kinetics have been initiated, and the manuscripts of two of these have already been sent to the Office of Standard Reference Data. A data center for radiation chemistry has been set up and is in the early stages of operation. A general Chemical Kinetics Information Center is also functioning at NBS, and already provides an index to over 11,000 selected papers.

Colloid and Surface Data

The Office of Standard Reference Data has joined with the NAS-NRC Committee on Colloid and Surface Chemistry to promote data compilation projects. Under this program data centers have been established on (1) light scattering, (2) critical micelle concentrations in association colloids, and (3) electrical properties of interfaces.

New Critical Evaluations.—A critical evaluation of the light-scattering properties of pure liquids is in the final stages of preparation. A major portion of the critical evaluation of data on critical micelle concentrations of colloid materials has been completed. The numerical information has been evaluated and put on machine cards to permit print-out of the data. New data are being reviewed and added to the file on a current basis. A critical analysis of techniques in this field is also being prepared.

Bibliography on Electrical Properties of Interfaces.—An extensive bibliography has been prepared on the electrical properties of interfaces, and the collected references are now being analyzed preparatory to the compilation of data.

Surface Tension of Molten Salts.—A collection of data on the surface tensions of molten salts has been completed, and evaluation of the data is now in progress.

Information Services

The development of the Information Services Operation of the Office of Standard Reference Data has proceeded with lesser emphasis than the production of new and expanded data compilations. However, substantial in-house progress was made in 1966. Specifically, the following activities were pursued:

1. Preparation of a bibliography of data compilations.
2. Construction and operation of a modified tape-typewriter to permit full use (selection, automatic encoding, storage and reproduction) of a bank of ninety selected auxiliary type faces. This typewriter will be used by several compilation projects at NBS for evaluation prior to wider use.
3. Continued analysis and follow-up of 16,000 answers to a questionnaire on needs for compilations of critically evaluated data.
4. A survey of approximately forty information centers within and outside the Federal Government.
5. The establishment of an NSRDS Newsletter, appearing monthly as a special section of the NBS Technical News Bulletin, and mailed as a separate reprint to over 2,500 interested individuals. The Newsletter first appeared in June 1966. Regular

This modified tape-typewriter permits full use (selection, automatic encoding, storage, and reproduction) of a bank of 90 auxiliary type faces. The "taxywriter," as it has been named, is being used in several data compilations at NBS, and its operation is being evaluated for wider use. Inset: Close-up of type face element being inserted in unit.

features include an updated list of publications from NSRDS, descriptions of specialized data centers and data compilation projects, information-handling projects and NSRDS news items.

6. The initial meeting of an Advisory Panel to the NSRDS Information Services Office.

INSTITUTE FOR MATERIALS RESEARCH

The Institute for Materials Research (IMR) has prime responsibility within the National Bureau of Standards for maintaining standards for materials measurements, materials measurement methodology, and numerical data which describe materials at the forefront of science and technology. The staff is predominantly scientific, and particular emphasis is placed on competence. The overall program is interdisciplinary in nature and requires expertise in nearly all of the physical sciences. Research is directed with emphasis and orientation dictated by current and anticipated national needs.

Programs are science based and support major NBS objectives, such as the establishment of standards of measurement, promotion of a uniform system of measurement, provision of critically evaluated numerical data, and provision of a scientific basis for establishing performance criteria. Because of the critical need for materials technology and standards for engineering and trade, IMR is in direct support of the Department of Commerce mission to assist and stimulate industry and commerce. In spite of mission orientation, the advanced state and interdisciplinary nature of modern materials science and technology requires IMR scientists to be active in and contribute to the development of nearly all of the physical sciences.

The primary objectives of IMR are to:

—Prepare and characterize materials needed for meaningful reproducible measurement of physical and chemical properties needed for engineering and science.

—Generate numerical data on well characterized materials which describe the physical and chemical properties of materials and the interaction of materials with their environments.

—Advance materials measurement methodology and theory.

—Disseminate reference materials which permit on-site calibration of measuring instruments, methods, and systems.

—Provide advisory, consulting, and research services to other

Government agencies for decision making, program evaluation, and problem solving.

—Analyze major national goals to determine extent of materials problems and identify potential solutions.

Specific accomplishments in the Institute's major program categories appear below.

RESEARCH MATERIALS

The research materials program involves the preparation and characterization of materials samples specifically for research. Advances in research materials are the forerunner of major advances in industry and science. This particular program is the essential basis for meaningful materials measurements, the development of measurement methodology, the generation of reliable data on the physical properties of materials, and the establishment of performance criteria which depend on materials. In addition to research samples, this program produces materials processing technology, instrumentation, and is the scientific and technological basis for standard reference materials. Samples are developed at NBS only when they are not readily available with sufficient purity or other required characteristics. Research materials are provided external to NBS when surplus samples are on hand or when the samples are urgently needed for significant anticipated advances in science or technology.

Crystal Growth and Characterization.—The National Bureau of Standards, aided substantially by a Crystal Growth and Characterization Program supported by Advanced Research Projects Agency (ARPA), became recognized as an outstanding international center for research on crystallization phenomena and crystal perfection. The theoretical and experimental studies of growth mechanisms and growth from solution of very high perfection, dislocation free crystals of ammonium dihydrogen phosphate were particularly effective.

Electronic Methods for Trace Characterization.—Several techniques and the associated apparatus based on residual resistance ratio and thermoelectric power were developed for characterizing research and standard reference materials. Residual ratio of the electrical resistance of a conductor at liquid helium temperatures (4 °K) to that at room temperature (300 °K), and at low temperature thermoelectric power are reliable and sensitive indicators of the effective electronic purities of pure metals and dilute alloys. An eddy-current system for measuring the residual resistance ratio has proven especially valuable for studies on pure copper, aluminum, gold, platinum, and zinc.

Superconducting Ceramics.—Discovery of superconductivity in an oxide semiconductor single crystal—strontium titanate—was reported by NBS scientists. Continuing research has shown this phenomena to occur also in polycrystalline specimens containing barium or calcium. Data compiled at the Bureau on the superconductive properties of these ceramic materials will substantially advance understanding of the phenomena.

"Three-Labeled" Glucose Synthesized.—Through the development of a 15-step process for synthesis of "3-labeled" glucose—^{14}C, intricate tracing experiments in the human brain have been made possible whereby normal and psychotic individuals can be differentiated. Methods were developed for synthesizing several radioactive heptoses (7-carbon sugars) containing carbon-14. Heretofore, no carbon-14-labeled heptoses were available for study. The new compounds will permit research workers in enzymology, biology, and biochemistry to study many complex processes by sensitive radiochemical methods.

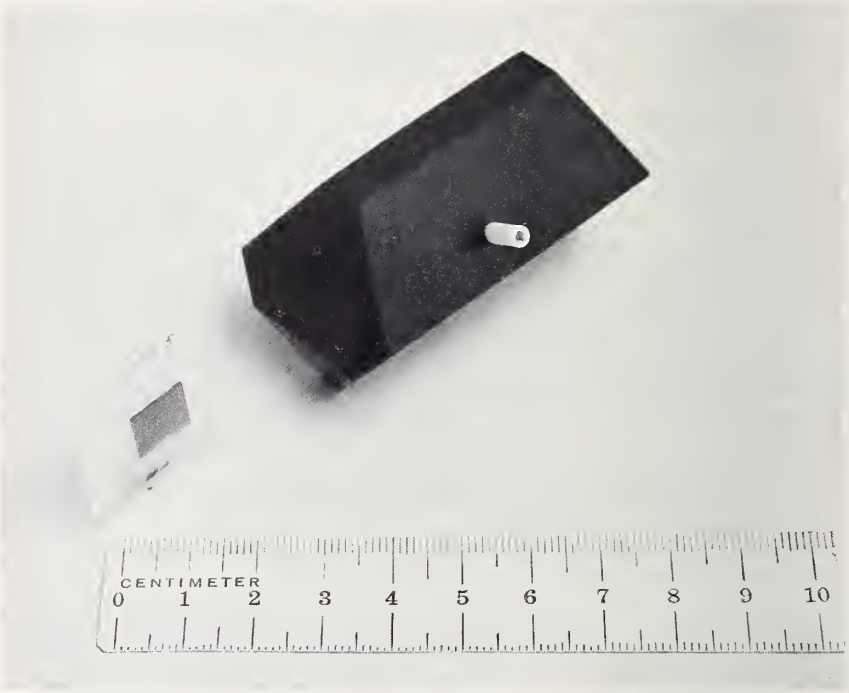
STANDARD REFERENCE MATERIALS

Standard Reference Materials are samples disseminated by NBS to be used in the calibration and evaluation of measuring instruments, methods, and systems. A major advantage is that a purchaser may calibrate his measurement system on-site at his convenience. Standards Reference Materials (1) provide quality control in industry, (2) facilitate the exchange of goods in commerce, and (3) define performance characteristics. Selection of samples to be provided by NBS is based on an evaluation of the requirements of science and industry. At present, about 600 different items are available.

In order to provide for the expanding needs of science and industry, 91 new items were added during the year; total sales amounted to about 70,000 standard samples sent to more than 2,000 companies.

Standard for Mössbauer Spectroscopy.—NBS accelerated development of Mössbauer spectroscopy by the development and dissemination of the first Mössbauer Standard Reference Material. This sample establishes a "bench mark" from which the chemical shift of all iron compounds will be measured. Chemists can now interpret the effect of changes in chemical structure in a more meaningful manner than before. In order to establish this reference standard with a minimum of systematic and random errors, a Mössbauer spectrometer that uses the fundamental NBS standards of time and length was designed. By use of an optical interferometric technique, a spectrometer with errors of measure-

ment small enough to allow the detection of a chemical shift as low as 0.0008 cm/s was constructed. This is a factor of ten smaller than that exhibited by the majority of spectrometers.



NBS Standard for Mössbauer spectroscopy is shown in its protective envelope next to a large single crystal of the material from which the standards are cut.

Isotopic Reference Standards.—Natural-ratio isotopic standards, calibrated on an absolute basis as a by-product of work on atomic weights, were issued for chlorine, bromine, copper, silver, and chromium. They are useful for defining mass-discrimination and other situations encountered in the operation of mass spectrometers. The isotopic standards for uranium containing more than 10 percent uranium-235, and the plutonium isotopic standard were improved during the year to provide a significant increase in accuracy.

New Steel Standards Issued.—Three new steel standards were certified to fill needs created by the development of new instruments and alloys. The first, a steel certified for the amount of carbon only, supplies the heavy demand for a reference to calibrate a new instrument for rapid determination of carbon in metals, yet conserves other more expensive, multielement, certified standards. The second is for calibration of instruments for

analysis of the relatively new type of age hardening (maraging) steel being developed for defense, aircraft and space uses. The third provides a reference material for analysis of the increasingly important alloys to which selenium has been added to improve the ease of machining.

New Glass Reference Materials.—Three commercial type glasses have been issued as NBS standard reference materials. These glasses have been certified for softening, annealing and strain points according to American Society for Testing and Materials specifications and test methods. Together with the two NBS viscosity standard glasses, they cover a wide range of glass compositions. They are used in the glass industry for quality and manufacturing cost control.

Microscopy Resolution Test Charts.—Explosive growth of literature of all types is a major problem to libraries. Universities, Government and industry are turning to microfilming, which has a market of approximately $300 million a year. The inherent capability of an instrument to provide microfilmed reproduction is needed to ensure the accuracy of retrieved data. Microscopy resolution test charts were developed at NBS for use in evaluating microfilm reproduction systems.

Calibration of New Reference Material.—Poly (methyl methacrylate) plates containing the dye solvent yellow 33, C. I. 4700, have been calibrated with respect to the fading of the dye by exposure to radiation in carbon-arc Fade-Ometers. Precise values of the transmittance of the plates at two wavelengths was determined as a function of radiation amount, and a set of calibration curves are in the process of being issued. These plates will be two new NBS Standard Reference Materials and are to be used in the control and comparison of Fade-Ometers and Weather-Ometers.

Thermal Emittance.—One of the prime factors that governs the heat balance and hence temperature of a body is the thermal emittance, or emissivity, of the material. This is of particular importance to the passive temperature control of electronically dense satellites of all kinds, where excessive heat or cold reduces the lifetime of the system. NBS has developed three thermal emittance standards covering the range 800 to 1600 °K. These standards are used for the on-site calibration of spectrometers which are in turn used to measure the emissivity of unknown or new materials. Such a scheme establishes performance criteria and encourages the proper selection of materials and design.

MATERIALS PROPERTY DATA AND MEASUREMENT METHODOLOGY

Current emphasis is on the generation of numerical data which describe the physical properties of materials. Carefully prepared and highly characterized reproducible materials are used as samples. The principal aims are to provide (1) needed reference data, (2) the relationship between the physical properties and the characterization parameters and (3) measurement methodology.

Basic measurements are made on both basic and engineering materials. Also, engineering properties are determined on engineering materials. The data generated become part of the NBS data bank for which the National Standard Reference Data System serves as the outlet. The data and technology generated is quite universal, being equally applicable in industry and science.

Potential standard reference materials are identified and the science and technology on which standard reference materials calibrations are based are generated under the program. This work is influenced by, and has a major impact on, the national research and development program; in addition it furnishes the data required for developing materials performance criteria required in engineering.

High Temperature Materials.—Stability of materials at high temperatures was investigated to determine decomposition pressures, species, phases, etc. These factors determine the chemical and dimensional stability and reliability of materials used in space systems and other high temperature applications.

Titanium Alloy Properties.—Stressed titanium alloys, in contact with salts (chlorides) at moderate to high temperatures, are known to fail by stress corrosion cracking. When used in supersonic aircraft, these alloys are subjected to stress conditions and failures can occur. Accordingly, NBS is subjecting specimens of these alloys to such environments to determine the mechanism, or cause, and thus be able to prevent possible catastrophic failures.

Properties of Oxygen.—NBS scientists accurately measured the density of liquid and gaseous oxygen at pressures up to 340 atm. During the measurements, a group of analysts developed an equation of state which permitted the calculation of extensive tables and charts of entropy, enthalpy and internal energy. Results could then be used immediately in effecting economy and efficiency by calculating mass rate of fuel consumption in mass reaction devices such as rockets.

International High Temperature Standards.—A number of scientists in IMR are members of an international task force (including representatives from Great Britain, France, Japan, Nor-

way, USA, and the USSR) organized to study high-temperature melting points. With scientific investigations and industrial technology now requiring precision measurements at higher temperatures, new reference temperatures must be provided. The melting point of alumina was chosen first to help fill a long-standing need for high-temperature reference points, in addition to those specified by the International Practical Temperature Scale of 1948. Measurements will be made by various techniques and the concerted efforts of the scientists of many countries should speed the research, improve the results and promote international acceptance of the standards.

Constant-Current Coulometry.—Constant-current coulometry has been up-graded by NBS research to the point that it now has the highest accuracy and precision of any method of chemical analysis, approaching 1 part in 100,000. Versatility has been increased through the use of additional oxidation-reduction systems.

Chromium Atomic Weight Redetermination.—A 6-inch mass spectrometer was designed and built for studies of the lighter elements. A new atomic weight of chromium was determined to be 51.9961 $\pm$0.0003 versus old mass spectrometry value of 51.996 $\pm$0.002. The atomic weight of magnesium is currently being redetermined.

Chemically Strengthened Glass.—Several mechanical properties of chemically strengthened glass were determined at elevated temperatures. Potential applications for this new glass are very interesting, for not only does it possess superior mechanical strength but it can be uniquely produced in thin cross sections which are relatively light in weight. Aircraft windshields, safety lenses, and underwater apparatus are examples of commodities for which it can be used. NBS studies provide engineers with the data needed in developing these applications.

Dental Material Tensile Strength Studied.—NBS applied a method usually used to determine the tensile strength of building materials, such as concrete, to small cylinders of dental amalgams and cements. This proved to be a simple and accurate method for following the increase in strength of dental size specimens from the time of insertion in the tooth until the material is fully hardened. The technique will be useful in the evaluation of new and presently available dental materials.

High Velocity Impact Strains in Fibers.—Performance of polymer filaments under stress due to high-velocity impact was studied. Flash photography was used to record the motion caused by rifle bullet impact. Strain distributions and time to break were

Examination of a specimen of chemically strengthened glass that is undergoing a rupture test.

obtained. Some textile fibers were able to withstand impact by stretching significant amounts within times less than 50 millionths of a second. Such information on the behavior of polymeric materials is used in the search for materials having superior impact performance.

New Technique for Surface Studies.—A new technique called ELF for studying surface phenomena was developed. It combines the individual techniques of *E*llipsometry, *L*ow energy electron diffraction, and Field emission microscopy. These three techniques, combined in a single instrument, permit the simultaneous measurement of extremely small amounts of material absorbed on the surface, characterization of the structure of the surface and the absorbed material, and determination the thermodynamic work function, coverages, and system cleanliness.

Dynamical and Structural Properties of Materials.—Neutron elastic and inelastic scattering techniques were applied to the study of a number of inorganic and organic molecular solids.

Infrared spectra and diffraction data were obtained in several cases to supplement the neutron results. The molecular systems and problems investigated include: (a) Rotational motions in methyl-substituted organics and their correlation with solid phase transitions and crystal structures, and (b) vibration spectra of yttrium and uranium hydrides and deuterides. The results were compared in detail with structural and thermodynamic properties. (c) The molecular motions, barriers to rotation and structure of a number of inorganic salts, including several ferroelectric materials. (d) Slow neutron energy spectra in ammonium acetate, carbonate, and citrate to obtain information on the ammonium ion motions in these compounds. (e) Hydrogen bonding in inorganic crystals.

Liquid Hydrogen Flow Meters.—Flow meters for liquid hydrogen appear feasible based on observed degree of proton spin relaxation occurring between two stations spaced a suitable distance apart along a pipe. In support of such a development, the proton longitudinal relaxation time, T_1, as a function of *ortho-para* composition and temperature was determined and published. NASA is sponsoring the commercial development of a working model flow meter based on these new data and technology. This new type of nuclear magnetic resonance meter may also be used to monitor the custody transfer (sale) of this important but difficult to measure commodity.

Precision Determination of the Coefficient of Expansion of Polyethylene.—The bulk coefficient of volume expansion of polyethylene has been measured by dilatometric techniques from 70 to 373 °K. This necessitated the development of a new dilatometric technique for operation at very low temperatures. The expansion of the lattice has also been measured by x-ray techniques and shown to be significantly different from the bulk expansion.

TECHNICAL ASSISTANCE TO OTHERS

To further utilize the technology and talent developed in IMR, advisory and consulting services are provided to governmental, non-profit, and industrial organizations at important stages of their planning and execution of programs with significant materials aspects. Such services are based on comprehension of the science which supports technology. Urgently needed testing services are sometimes rendered to other Government agencies not having suitable facilities of their own. IMR outputs of data on properties of materials and measurement systems are made available to national and international standardizing bodies, and consultative services are given on utilization of this information.

Air Pollution.—NBS found that a variety of products were formed when aromatic hydrocarbons, adsorbed on particulate matter, were treated with air and light. Photochemical oxidation of polycyclic, aromatic hydrocarbons adsorbed on air-borne particles takes place readily in the atmosphere and gives rise to a variety of compounds, some of which may play an important role in air pollution. Pyrene (an important air-pollutant) adsorbed on silica gel was found to give many oxidation products. Two of these, 0.6–pyrenedione and 1.8–pyrenedione, have now been identified. Procedures for the preparation, separation and determination of these and related compounds were developed, and samples of the pure compounds were supplied as reference materials to other laboratories engaged in studies of air pollution.

NBS Report Serves as a Military Text.—An NBS report describing the results of a metallurgical examination of a fractured rod end fitting from a helicopter was prescribed for study by all military classes at the Aerospace Safety Division of the University of California.

Investigations of Fire and Explosion at Cambridge Electronic Accelerator.—The AEC requested the assistance of the Cryogenics Division of IMR in the investigation and identification of the cause of the explosion and fire which demolished the Experimental Hall of the Cambridge Electronic Accelerator. The liquid hydrogen technology and safety procedures associated with a large liquid hydrogen bubble chamber were of particular concern. Design philosophy, operating procedures, and physical damage were examined in cooperation with other major national laboratories in identifying the most probable sequence of events.

Corrosion Research for the Office of Saline Water.—The Institute for Materials Research was requested by the Office of Saline Water, Department of the Interior, to establish research in relevant aspects of corrosion. Emphasis is on providing a scientific basis for the most economical selection and utilization of materials for desalination plants. Research is aimed at understanding, under practical desalination conditions, how corrosion occurs and how it may be predicted and controlled. The program is multidisciplinary in nature and will fully utilize the many years of practical experience gained at NBS through corrosion research.

Automotive Seat Belt Standards.—NBS assisted in promulgating a standard for maintaining the quality of seat belts. The Institute for Materials Research laboratories provided much of the data required to evaluate the compliance of newly manufactured belts with requirements.

Propellant Performance.—At the request of NASA Lewis Research Center, numerous prelaunch and in-flight problems associated with the liquid hydrogen fueled Atlas-Centaur rocket were pursued at NBS. Experiments were conducted to determine the response time and configuration effects on both liquid level gages and temperature sensors. The behavior of these instruments must be known to assure prudent propellant loading and utilization.

Aircraft Failure Causes.—NBS conducts metallurgical investigations of aircraft components that have failed in service with the object of determining the cause of the failure and preventing a recurrence. Many different parts were examined, such as pieces from an aircraft to determine the origin of an in-flight fire, the failure of a compressor disk from an engine, or the fracture of a helicopter blade. The analysis considers such causes of failure as improper heat treatment, fabrication faults, misalignment, improper design, assembly errors, and improper selection of materials. The material conditions observed are evaluated and remedial treatments recommended. Technical sleuthing is usually involved. For example, the fire and crash accompanying an accident can cause considerable damage to the fractured metal surface. Careful and meticulous cleaning is essential and only the beginning of the analysis.

Lunar Exploration.—A unique sanitary, single-crystal x-ray spectrometer has been developed at NBS in association with the lunar geology effort, NASA Goddard Space Flight Center. The device, scheduled for completion before the end of the calendar year 1966, will be used in experimentation leading to the development of equipment for lunar geologic exploration.

INSTITUTE FOR APPLIED TECHNOLOGY

The Institute for Applied Technology (IAT) develops criteria for the evaluation of the performance of technological products and services and provides specialized information services to meet the needs of the Nation's industrial community. Organizational structure is related to major industrial sectors and to areas of technological competence.

The Institute also seeks to create opportunities for the application of science and technology to industry and Government. This role of facilitating the maximum use of science and technology in our economy is part of the broad mission of the Department of Commerce. Thus, Institute personnel continually scan and analyze the state of American technological development to identify proper opportunities for the Institute to direct its resources and develop its programs.

There are many opportunities to use the results of research and development more effectively. The Institute for Applied Technology identifies and undertakes those tasks which are appropriate to the National Bureau of Standards leadership role in the national measurement system. These fall into the following broad areas:

1. Engineering measurements and standards.
2. Dissemination of technical information to industry, Government, and the technical community.
3. Invention and innovation.
4. Systems analysis.
5. Technical assistance to other Government agencies.
6. Exploratory research.

ENGINEERING MEASUREMENTS AND STANDARDS

This is the Institute for Applied Technology's primary link to the measurement system. The Institute's function here is to provide a sound technical basis, in the form of test methods and per-

formance criteria, for standards, specifications and codes in a variety of fields with special emphasis on building construction, automatic data processing, and electronic instrumentation.

In addition, the Institute provides links to organizations which develop and administer standards, codes and specifications. Its role is to identify technical problems which need solving to assure the availability of a sound technical base for the Nation's standards, codes and specifications.

MEASUREMENTS AND STANDARDS

Electronic Instrumentation

NBS conducts a program to provide technological support to the electronics industry through improving the yield, performance, and reliability of discrete and integrated semiconductor devices. The program currently is concentrating on measurement methods for materials of present engineering importance (silicon and germanium), including measurements of transport properties (such as resistivity and lifetime), detection and identification of flaws in materials, measurement and control of material properties during processing, and correlation of device properties with material characteristics.

Semiconductor Flaw Study Initiated.—Scientists of the NBS electron devices laboratory have embarked on an investigation of defects in semiconductor materials, in order to help industry produce more reliable devices. The materials being studied are silicon and germanium. They are essential in the fabrication of transistors and diodes which are now coming to be more widely used in radios and "hi-fi's," as well as in more specialized electronic assemblies. Reliability of these semiconductor components, and of the more sophisticated integrated circuits using the same materials, is essential to modern scientific instrumentation, advanced weaponry, and the communications systems for our national security and space programs.

Silicon Radiation Detector Developed.—A silicon radiation detector developed and fabricated by NBS was used in the initial NASA Solar Proton Monitoring Experiment. The objective was to monitor the frequency of occurrence of solar events and the flux and energy spectrum of the protons emitted therefrom by using these detectors in satellites and rockets. The detectors, lithium-compensated silicon diodes, were fabricated under a program to investigate materials, performance and methods of measurements of radiation detectors.

Silicon Attenuators for Laser Measurements.—Attenuators composed of elemental silicon have been used for ruby and gallium

arsenide laser beam measurements. Unlike conventional glass attenuation filters, the pure silicon disks can be obtained at low cost and remain unchanged in attenuation factor. The silicon attenuates the laser beam by means of a reradiation process, reducing intensity sufficiently for the output pulse shape to be measured by calibrated photomultipliers.

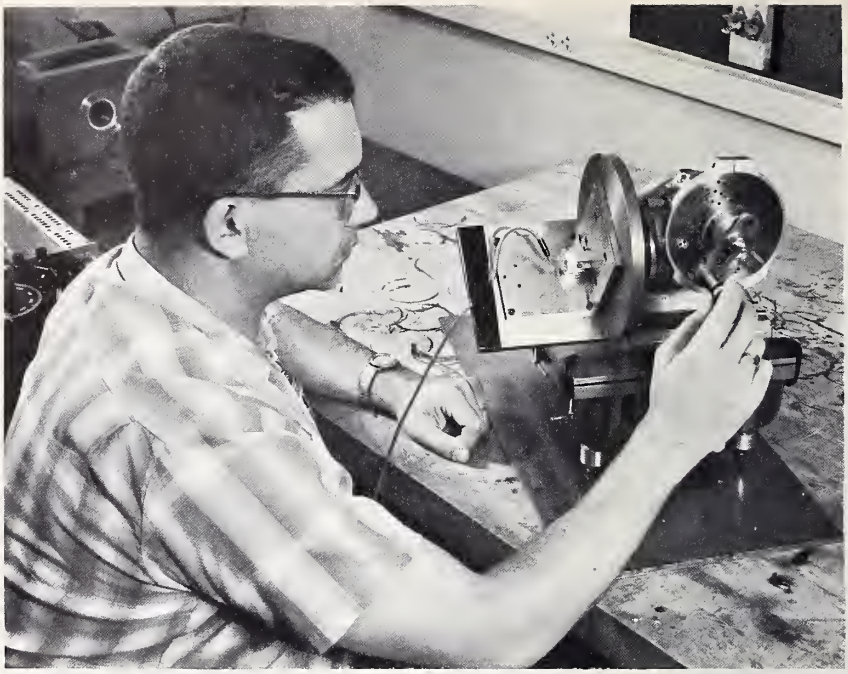
Avoiding Transistor Breakdown.—A study has identified the conditions under which a transistor failure known as "second breakdown" occurs. Data from the study will aid electronic designers in producing more reliable equipment by avoiding this type of failure.

Technique to Predict Transistor Failure.—A three year NBS study of transistors shows that certain data can be used to predict failure of these electronic components before they are placed in service. These findings may pave the way toward a new dimension of reliability in transistorized equipment, from hi-fi amplifiers to space instrumentation. The technique of accelerated aging was used in which the transistors are tested after periods of exposure to above-normal temperatures. It was found that measurements of transistor performance after six weeks of accelerated aging can usually determine which transistors will fail in the first two years of service.

NBS Device Calibrates Accelerometers.—NBS scientists have assembled a simplified device for the accurate calibration of accelerometers. This device uses the earth's gravitational field as a reference, and therefore provides the ultimate in reliability without requiring the user to depend on NBS calibration services. The growth of engineering capability during the last decade, particularly in the aerospace field, has greatly increased the requirements on acceleration measuring devices. With the large volume of such instruments to be calibrated, NBS has placed increased emphasis on the development of procedures with which instrument users can perform their own calibrations.

New Microwave Discharge Cavities.—Two microwave discharge cavities that offer many advantages in atomic and molecular research were developed. The new cavities offer high efficiency and added convenience, producing high ionization with minimum heating, contamination, and electrical interference. Discharges in microwave cavities are useful as a means of exciting atoms for studying gaseous electronics, producing light, and obtaining free radicals (intensely chemically reactive molecular fragments) for a wide variety of scientific studies.

Cryogenic Cooler for Semiconductor Devices.—Precisely controlled cryogenic ambients were obtained by use of a special lab-



This NBS device provides highly accurate and reproducible calibrations of acceleration to 1 *g* by reference to earth's gravitational field.

oratory cooler developed at NBS. The cooler removes heat developed within semiconductor devices to permit operation at low temperatures. It is particularly useful in investigations involving light emitters, lasers, and photodetectors because it enables these devices to be operated at cryogenic temperatures without being enclosed; otherwise optical windows would be required. Because the cooler operates by directing a stream of cold gas on the cooled device, it can supply controlled cooling to a variety of laboratory setups.

Building Research

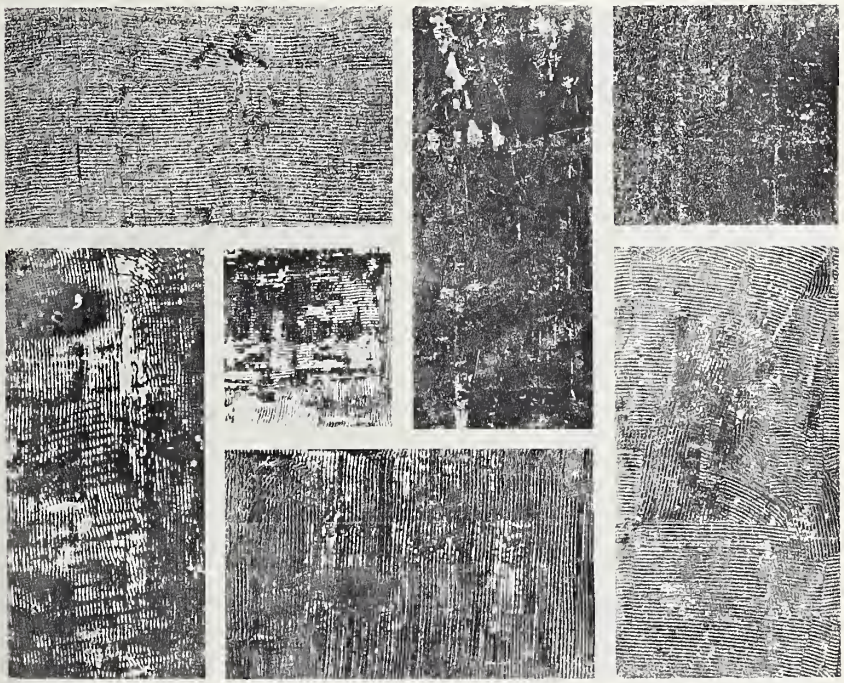
The Building Research Division was reorganized in order that it could more directly assist development of the performance concept as a basis for engineering measurement. To further this aim, the Division is now engaged in four major work programs:

1. Identification of performance criteria in buildings.
2. Identification or development of test methods.
3. Determination of performance which can be measured and tested.
4. Pilot studies.

Weather Resistance of Porcelain Enamels.—Seven types of por-

celain enamels were studied for weather resistance. The specimens had been exposed for seven years to various weather conditions throughout the U.S. The results show that the major factors affecting color and gloss retention are atmospheric humidity and acidity and the acid resistance of the porcelain enamel.

Bonding of Tile and Paint to Treated Concrete.—The adhesion of resilient tile flooring and paints to concrete surfaces treated with curing or parting agents was explored. In this study, sponsored by the Army, Navy, and Air Force, it was found that asphalt cutback adhesive (a solvent-type asphalt adhesive) may be used successfully over most treated concrete surfaces. However, asphalt emulsion adhesive requires an asphalt primer to insure adhesion, particularly when used over oily or waxy material. Paints formulated with butadiene-styrene copolymer or chlorinated rubber in organic solvents appear to have the best adhesion to treated concrete.



Photographs of experimental specimens that were used in a study of the bonding of tile to treated concrete. The photographs show concrete-specimen surfaces after removal of the tile.

Xenon and Carbon Arc Weatherometers Compared.—NBS scientists recently compared the carbon-arc and the xenon-arc weatherometers as devices for laboratory weathering of coating-grade

asphalts. The results of the study show general agreement between the asphalt durabilities obtained with the two sources when American Society for Testing and Materials test methods were used. However, considerable variation in durability was detected by more sensitive analytical methods.

Concrete Failure Due to Corrosion.—A study was undertaken of some corrosion problems that have developed in recent years because of the use of dissimilar metals embedded in cementing materials. It was found that the different metals form a short-circuited galvanic cell battery. The resulting corrosion leads to failure of steel-reinforced concrete. Examples of failures were presented. Some of the variables that affect the degree of corrosion were discussed and some general precautionary measures were recommended.

Smoke Danger from Burning Aircraft.—A study was completed of one phase of a contract from the Federal Aviation Agency on the smoke generated by burning aircraft materials. Smoke measurements and the approximate concentration of some poisonous byproducts resulting from flaming and smoldering fires were determined for a number of materials usually found aboard airplanes. Charts and tables were produced which aid in estimating approximate smoke and gas concentrations which would exist if an airplane catches fire. Results of this and similar studies will enable engineers to choose materials for aircraft that will produce a minimum of dangerous smoke in a fire. Results will also be useful in designing systems for removal of any smoke that is generated.

New Method for Measuring Smoke Density from Burning Materials.—A laboratory test was developed for the photometric measurement of smoke density. The smoke generated from a burning building represents a major threat to the lives of occupants. In addition to the large concentrations of carbon monoxide and other toxic materials present in smoke, the obscuration of vision often hinders rescue operations and prevents escape by occupants. The method used in the NBS investigation assumes the applicability of Bouguer's law to the attenuation of visible light by smoke. Smoke quantity is therefore reported in terms of optical density rather than light.

Scaling Factors for Fires.—Large-scale fire research experiments are expensive and difficult to analyze because of the interactions of mechanical, chemical, thermal, and diffusional processes. Although these interactions also complicate analysis of fires in small-scale models, the use of such models under controlled conditions can provide useful information at much less cost. To facili-

tate their application, NBS initiated a study to develop basic information on the use of small-scale models in fire research. In this study, three different sizes of model enclosures were investigated. Scaling relationships were found between the sizes which may be useful in relating the models to full-scale structures. The scaling relationships were obtained by "normalizing" the burning rate and ventilation parameter.

Colorimetric Determination of Gaseous Combustion Products.—The development of fire extinguishing agents has always been done empirically, because no entirely satisfactory theory exists to explain some chemical reactions in flames. Even less is known about the changes in such reactions produced by chemical extinguishing agents. A study is now under way to gain a better understanding of these changes. In this study a colorimetric procedure was developed for the separate determination of HBr and Br_2 which occur as gas-phase constituents of combustion inhibited flames.

Thermal Conductivity of Beryllium.—A special antenna for a space vehicle was made of 2–inch wide heat-treated beryllium-copper strip 0.002–inch thick. The device is made in coiled form and released in space to form a very long straight tube. Accurate thermal conductivity data for the strip were needed to calculate temperature effects on the shape of the extended antenna. The measurements had to be made on samples of the strip because of its special heat-treatment. Bar specimens were made of two different alloys by stacking side by side many layers of strip held together tightly by transverse bolts. The measurements were successfully made over the temperature range —150 to 200 °C, with estimated uncertainties of 3 percent for one alloy and 5 percent for the second.

Thermal Conductivity of Platinum Reference Material.—Recent completion of a laboratory investigation of the thermal conductivity and electrical resistivity of 99.987 percent pure platinum from 373 to 1373 °K marked a milestone in efforts to supply industrial and other laboratories with standard reference materials for calibrating their apparatus. Electrical and nonelectrical methods were employed in the investigation to determine the thermal conductivity of the same specimen in the same apparatus, allowing direct comparisons of the two different methods of measurement. The two methods agreed within acceptable limits of experimental error and the data obtained were considered accurate to better than 1 percent. It was concluded that platinum can be established as a standard reference material for thermal conductivity from 0 to 1000 °C.

PERFORMANCE CRITERIA

Recently, emphasis has been placed on the use of performance criteria, as contrasted with measurements based on narrowly drawn engineering specifications. Both within the Federal Government and in private industry the performance concept is being recognized as a more flexible method of setting engineering standards. In addition, this concept provides for maximum expression of creativity and innovation among builders and manufacturers, because attention is focused on the function of a particular system, rather than on the system itself.

Pressure Transducer Response Affected by Thermal Gradients.—A recent study disclosed that the performance specifications of many flush-diaphragm pressure transducers do not describe their actual performance when they are subjected to thermal gradients. The degradation of performance is temporary; the response typically returns within its specified limits when thermal equilibrium is regained. This aberration is detected by a procedure developed for testing transducer performance under controlled conditions of thermal shock.

Properties of Semiconductor Materials.—The NBS Electron Devices Section is engaged in studies of the correlations between the properties of semiconductor materials and the performance of semiconductor devices fabricated from such materials. Presently, the effects of carrier life-times and mobility and impurities, such as oxygen, copper, and gold in germanium, on the performance and stability of gamma ray detectors are being investigated. The use of germanium gamma ray detectors for such applications as activation analysis, photonuclear reaction studies, decay scheme investigations and Mössbauer spectroscopy is expected to increase in the near future.

Fire and Smoke Resistance of Doors Evaluated.—A study was undertaken to determine the effectiveness of door modifications in increasing their fire-resistance value. The study revealed that doors may be modified to increase their fire resistance, but the modifications do not make them comparable to rated fire doors. None of the doors that were investigated proved to be effective barriers to the passage of smoke. The study also considered the feasibility of controlling the smoke flow past the doors by modifying the edges and changing the neutral pressure zone of adjoining rooms.

Dynamic Thermal Performance of Exterior Walls.—As part of a large-scale program to determine characteristics and criteria of exterior wall systems, undertaken for the Federal Housing Administration, an investigation was made of the thermal perform-

ance of walls of composite construction when they are exposed to periodically varying outdoor conditions of solar radiation and air temperature change. A test method was devised, and a mathematical analysis was made of its use in determining two effective thermal parameters for composite wall construction.

Data on Coincident Extremes of Weather for Evaluating Protective Fallout Shelters.—Coincident diurnal values of dry-bulb temperature, dewpoint temperature and solar radiation during hot and humid days have been statistically processed for the dynamic analysis of the fallout shelter thermal environment. This technique of incorporating the outdoor weather data with the thermal environment in the shelter is considered to be a refinement over the existing methodology, which is based upon design dry- and wet-bulb temperatures listed in the Guide and Data Book of the American Society of Heating, Refrigerating and Air Conditioning Engineers.

Testing and Rating the Cooling Load of Refrigerated Truck Bodies.—A method for testing and rating the heat, moisture, and air transmission characteristics of refrigerated delivery truck bodies was developed. The method is particularly useful for vehicles used in "stop and go" delivery of perishable, chilled or frozen food. The program was jointly sponsored by NBS, U. S. Department of Agriculture and the Truck-Body and Equipment Association. The method allows determination of pertinent characteristics from rate-of-weight gain data and a simplified calorimetric technique for obtaining the total cooling load. Development of this method provides a base for promulgation of standards for testing and rating truck bodies by Government, industrial and commercial laboratories.

LINKING ENGINEERING MEASUREMENTS AND PERFORMANCE CRITERIA TO STANDARDS

Product Standardization Updated.—Procedures for standardizing industrial products have recently been revised. The new procedures will apply to the 40 proposals which the NBS Office of Product Standards has received for new standards, ranging from pressure sensitive tape to wood garage doors. These standards, which are now considered tentative, are being reviewed to assure their technical soundness. When they are found to be generally acceptable by the manufacturers, distributors and users of these products and in accord with the public interest, they will be published for voluntary use.

Package Checking Procedures for Aerosol Products.—NBS developed a simple, rapid procedure for checking the delivered

weight of aerosol products. The Chemical Specialties Manufacturers Association and industry cooperated with the NBS Office of Weights and Measures in developing the testing techniques, which will be used by both aerosol packagers and weights and measures officials.

Auto Seat Belt Standards Revised.—In April 1966 proposed changes were published for the auto seat belt standards first announced last December. With slight revision these changes have now been incorporated in the standards; in this form the standards became mandatory on December 31, 1965. Beginning on that day, the manufacture, sale, or transportation in interstate commerce of seat belts which do not meet the revised standards would be unlawful. The standards with the revisions were printed in the July 1, 1965 *Federal Register*. The standards cover three types of seat belt assembles: a lap belt, a safety harness for adults, and a safety harness for children. The lap belt provides restraint only on the pelvis and is designed for situations where movement of the upper part of the body is not likely to cause injury. The safety harness provides restraint both on the pelvis and the upper torso and is designed for situations where movement of the entire body must be restricted to avoid injury. The standards permit the safety harness for adults to be either an integral harness or a combination of lap and shoulder belts.

Seat Belt Tester Capable of Simulating Automobile Crashes.—A dynamic seat belt test machine capable of simulating key aspects of an automobile crash has been developed. NBS has, and will continue to utilize, various tests for seat belts—including abrasion and tension testing—but the new machine is of particular interest because it provides a means of testing conventional seat belts under conditions closely approximating those present during vehicle operation. The machine is composed of a sled carrying a seat and dummy which is accelerated by means of a flywheel through a tow tape attached to the sled. The machine is designed to accelerate the sled and dummy (together weighing about 400 pounds) to 30 miles per hour in a space of 19 inches and a time of 0.072 second. This produces an acceleration of around 30 Gs.

National Scale Seminar.—A National Scale Seminar covering weights and measures considerations was sponsored jointly by the NBS Office of Weights and Measures and the Scale Manufacturers Association. The basic purpose of the seminar was to expose representatives of the scale industry to weights and measures supervision.

DISSEMINATION OF TECHNICAL INFORMATION

The Institute's technical information program is built around the Clearinghouse for Federal Scientific and Technical Information, which serves as the central point of contact in the Federal Government for disseminating the results of Government-sponsored research and development to industry, commerce and the general public. In addition, the Institute maintains certain specialized technical information centers.

THE CLEARINGHOUSE

Fiscal year 1966 marked the second full year of operation for the Clearinghouse. As expected, the work load and output of this facility increased substantially. The two Clearinghouse indexes (U.S. Government Research and Development Reports and Technical Translations, a report of foreign translations into the English language) announced 29,000 and 20,000 titles, respectively. The total title collection in the Clearinghouse now numbers 455,000, which is an increase of almost 14 percent over fiscal 1965. In addition, the Clearinghouse issued 1,825,000 copies of research reports, an increase of better than 23 percent over last year.

New Patent Subscription Service.—The Clearinghouse began offering 16 mm microfilm of all new patents issued by the U. S. Patent Office and reported in the *Official Gazette.* It is estimated that 67,000 patents issued annually by the Patent Office will be made available to subscribers. Subscribers may purchase the total or one of three categories—electrical, mechanical or chemical.

Government-Wide Index.—A Government-wide index to Federal Research and Development Reports is now being published twice a month as a companion publication to U. S. Government Research and Development Reports. It completely indexes USGRDR and includes entries from current issues of other Government abstract journals. Documents are indexed by subject, author, contracting or performing organization, report number, and contract number.

Federally Sponsored Research Announcements.—The Clearinghouse, in cooperation with the National Science Foundation and the Science Information Exchange began to announce Federally sponsored research and development underway. The U. S. Government Research and Development Reports publication was recently expanded to include a section listing current unclassified Government-sponsored research and development projects. Intended to prevent costly duplication of research in the physical sciences, engineering and related technology, the listings include

project, title, performing organization, principal investigators and term of contract or grant.

Engineers Joint Council Thesaurus.—Identifier words used in indexing reports in *USGRDR* over the past year were reviewed, edited, and standardized according to Engineers Joint Council (EJC) specifications by the Clearinghouse lexicographer. These terms will be candidate items for input to the revision of the "EJC Thesaurus of Engineering Terms." The items will be key punched and presented to EJC in machine-readable form.

USGRDR Publication Expanded.—U. S. Government Research and Development Reports (USGRDR) announced the availability of selected new reports of U. S. Government-sponsored R&D released by the Department of Defense, the Atomic Energy Commission, National Aeronautics and Space Administration, and other agencies. Entries are arranged under 22 subject categories. This system was adopted by the Committee on Scientific and Technical Information (COSATI) of the Federal Council on Science and Technology.

Foreign Technology and Translations.—The Clearinghouse Foreign Technology and Translations Program is focused toward collecting, editing, announcing, and making foreign scientific and technical information available to industry, commerce, and the general public. Inputs to this mission are derived from the Federal community, the industrial community, the public, and from foreign government and industrial communities.

International Customs Journal Now Available.—Permanent reference copies of the International Customs Journals can now be purchased by U. S. exporters from the Clearinghouse. Published by the International Customs Tariffs Bureau in Brussels, the Journals consist of translations of the national customs tariffs of various countries, as well as other official pronouncements bearing on their custom systems.

Heretofore the U.S. Department of Commerce has only been able to furnish businessmen with copies on a loan basis since the International Customs Tariffs Bureau restricts distribution of copies of the Journals to member governments. The Department recently made arrangements, however, which enable it to sell reproductions of the Journals to exporters for their permanent use.

Foreign Market Surveys Sold by Clearinghouse.—A series of *Foreign Market Surveys* have been prepared by overseas market research firms for the Business and Defense Services Administration, U. S. Department of Commerce, as part of a United States program to help U. S. firms initiate, develop, or expand their ex-

ports. The Surveys join a growing list of publications now available to U. S. businessmen through the NBS Clearinghouse.

TEXTILE AND APPAREL TECHNOLOGY

The Textile and Apparel Technology Center functions with funds provided by the Congress under the Civilian Industrial Technology (CIT) appropriation in fiscal year 1963 and subsequently. The money was made available to encourage the textile and apparel industries' efforts to develop ways of coping with the pressures of economic cycles, foreign competition, displacement by other materials, changing consumer demands, and the impact of new materials. Projects have been chosen with the aim of helping to begin institutional activities which the industry itself will continue to support.

Apparel Research Foundation.—IAT helped in organizing and financing the Apparel Research Foundation (ARF) to spur technological progress in the apparel manufacturing industry. Dues from members and financial support from IAT has resulted in research aimed at development of newer types of garment machinery.

Cotton Yarn Strength Tables.—The NBS Textile and Apparel Technology Center contracted for the development of Cotton Yarn Strength Tables. These reference tables can predict the tensile strength of yarns spun from cotton and other fibers. Use of these tables saves much time since testing requirements have been reduced from 40 tests to 3 tests.

Simulation Models for Textile Industries.—A report was issued providing information necessary for construction and validation of simulation models of the tufted carpet and ladies' seamless hosiery subindustries. This information is in three levels of detail. The first level is a general description of the manufacture of tufted carpet or ladies' seamless hosiery, the manufacture of the yarn used in producing these products, and the distribution of tufted carpet or ladies' seamless hosiery to the retail consumer. The second level of detail is found in the subindustry function diagrams and a description of each of their functions and flows. The third level of detail is in the data tabulations prepared under separate cover. The report helps manufacturers of various textiles to recognize interactions in the total system from raw materials to distribution of a finished product.

Textile Dye Survey Completed.—An important survey of the present need for fundamental and applied research in the textile dyeing process has recently been completed by the Massachusetts

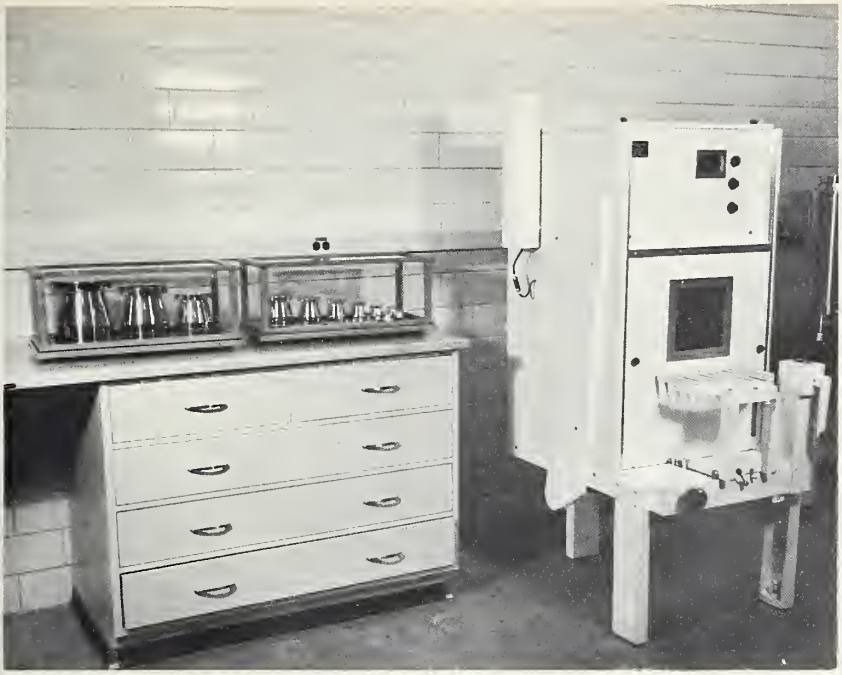
Institute of Technology. Heretofore, the development of a specialized system to dye a new material was done empirically and not systematically. This study sets forth the areas of basic research that must be explored in order to develop improved dyes. It is hoped that this survey will help to correlate an estimated 10 million dollar annual industry effort to develop new dyes.

Thesaurus of Textile Terms Aids Industry.—A thesaurus of textile and apparel terms has been completed. The document is heralded as an extremely valuable step in computerizing certain aspects of the textile industry. The thesaurus is compatible with those of the Joint Engineers Council and the American Society for Metals, which will make it possible to join the three systems by telephone and search their literature simultaneously. The system, when complete, will be of great value to all scientific and technical workers in the textile, apparel, and related industries. Currently, editors of appropriate journals are using the thesaurus to index and store information on 20 years of literature in the field.

ENGINEERING STANDARDS

Standards Communication Center.—A Standards Communication Center was recently established in an effort to remedy one aspect of the serious problem that exists in the area of standards information. The long range objective of the Center is to provide a reference service capable of furnishing the most accurate, current, and complete information available concerning domestic standards and standarization activity. It is anticipated that the scope of the Center will be expanded gradually to include foreign and international standards. The material in the Standards Communication Center will consist of all available domestic standards in current use; federal and military specifications and standards; books and periodicals pertaining to standards and standardization; and items such as committee reports and drafts of standards, press releases, and newsletters.

Metrology Laboratory for Latin American Countries.—As part of the State Department's Agency for International Development program, a metrology training center has been installed in Bogota, Colombia. Staff members from the NBS Office of Weights and Measures conducted a training course in the new facility for government officials and inspectors of three Latin American countries —Colombia, Ecuador, and Venezuela. Located at the National University in Bogota, Colombia, the new laboratory has been equipped with length, mass, and volume standards calibrated at NBS. Weights and measures field standards similar to those used in this country have also been installed.



On the left, mass standards designed at NBS for the new metrology lab in Bogotá, Colombia. These standards range in size from 1 mg to 30 kg. At right is a 30-kg precision one-arm balance, also developed for the laboratory.

BUILDING RESEARCH

New Building Research Publication Series.—A new publication entitled Building Science Series was begun. The series is designed to disseminate technical information developed at the Bureau on building materials, components, systems, and whole structures. Presented are research results, test methods, and performance criteria related to structural and environmental functions and the durability and safety characteristics of building elements and systems. The series is directed toward the manufacturing, design, and construction segments of the building industry, standards organizations, officials responsible for building codes, and scientists and engineers concerned with the properties of building materials.

INVENTION AND INNOVATION

In general, the mission of the Office of Invention and Innovation (OI&I) is to help develop an environment more conducive to technological change. OI&I seeks to do this in three principal ways, one providing a more rational basis for the formulation of climate-setting federal policies, another offering programs of

assistance to inventors, and the third through education. Brief descriptions of major OI&I activities and their origins follow.

Education in the Techniques of Invention and Innovation.—This program, which stems from a recommendation of the National Inventors Council, explores with the universities, opportunities for teaching the techniques of invention and innovation. A principal activity in this program is the preparation of challenging design cases, based on real, unsolved problems facing NBS staff. These cases will be provided first to engineering schools and, ultimately, as the program progresses, to schools of business administration as well.

National Conference on Creative Engineering.—With support from the NBS Office of Invention and Innovation, a National Conference on Creative Engineering Education was held in Woods Hole, Massachusetts, in September 1965. Over one hundred eminent educators, inventors, innovators, entrepreneurs, and Government officials discussed methods of bringing the techniques of invention and innovation into engineering education, and thereby, to make engineering a better instrument for solving the growing problems of mankind. A survey of findings and recommendations of this group was published by NBS.

Invention Expositions.—A total of 13 State invention expositions were held in fiscal year 1966. These activities are usually run by State organizations; NBS provides expert help in planning and running the events. In addition, several brochures describing how to plan and run an invention exposition were prepared and distributed by NBS.

National Inventors Council Reconstituted.—The National Inventors Council adopted a new charter and appointed Daniel V. De Simone, Chief of the NBS office of Invention and Innovation, to the position of Executive Director. Under its new charter the Council is concerned with the processes of inventions, the work of inventors, and ways to provide for effective assistance to them through State, regional and Federal invention programs. This group works closely with the NBS Office of Invention and Innovation.

SYSTEMS ANALYSIS

Research in the Institute for Applied Technology is strongly committed to the systems concept, a technique to determine the entire performance of a man-machine complex or activity. It is used to solve problems which are so complex that a single discipline cannot normally resolve the many ramifications of a problem. The systems analysis approach seeks to make all parts of

the system work toward a unified best solution, not one which makes one segment of the system work perfectly.

Transportation Simulation Studies Continued.—Development continued on a series of simulation tasks pertaining to the transportation system of the Northeast Corridor for the Office of Transportation of the Department of Commerce. The purpose of this research is to provide a framework, methodology, and mathematical models which will permit measurement and evaluation of the engineering, economic, and social factors essential to decision-making on national transportation policies.

Study of World-Wide Seismology Net.—The NBS Technical Analysis Division is undertaking a cost-benefit study of the World-Wide Seismology Net (WWSN). This Net, operated by the Environmental Science Services Administration, monitors earthquakes and other earth disturbances and helps confirm the occurrence of nuclear explosions all over the world. The use of the data generated by the Seismology Net has never before been critically studied.

NBS to Study Benefits of International Standardization.—NBS is undertaking a study to determine the precise impact that differences in foreign and American standards have on international trade and the U. S. economy. Attempts to increase American exports are hampered by differences in foreign and American standards. This is critically important now in the face of our continuing balance of payments crisis. The study by the NBS Technical Analysis Division will determine the effects of greater U.S. participation in international standards-making organizations. The Technical Analysis Division will describe and measure every factor of the international standards program which relates to the growth and maintenance of American markets overseas.

Aid to Weather Bureau in Planning Services.—A cost-benefit study of weather forecasting for the U.S. Weather Bureau is underway which should help the Weather Bureau improve its services to the public. The primary objective of the program is to establish a set of measures of social and economic benefits in the relationship between man, the weather, and the Weather Bureau. Baltimore, Maryland, was designated as the site of this first comprehensive study. Results will help the Weather Bureau plan programs that will better serve the needs of industry, Government, and the public.

Study Aids in Earthquake Protection.—With the Coast and Geodetic Survey, a study was completed which promises to be highly useful in the protection of life and property from the menace of earthquakes. The study is the first phase of a complete

survey. However, it already indicates quite clearly the benefits of using data from the C&GS Engineering Seismology Program in building design and construction. Conversely, it shows the penalties paid for ignoring such information.

TECHNICAL ASSISTANCE TO OTHERS

In its field of special competence, the Institute provides advice and assistance in the form of technical development to other Government agencies.

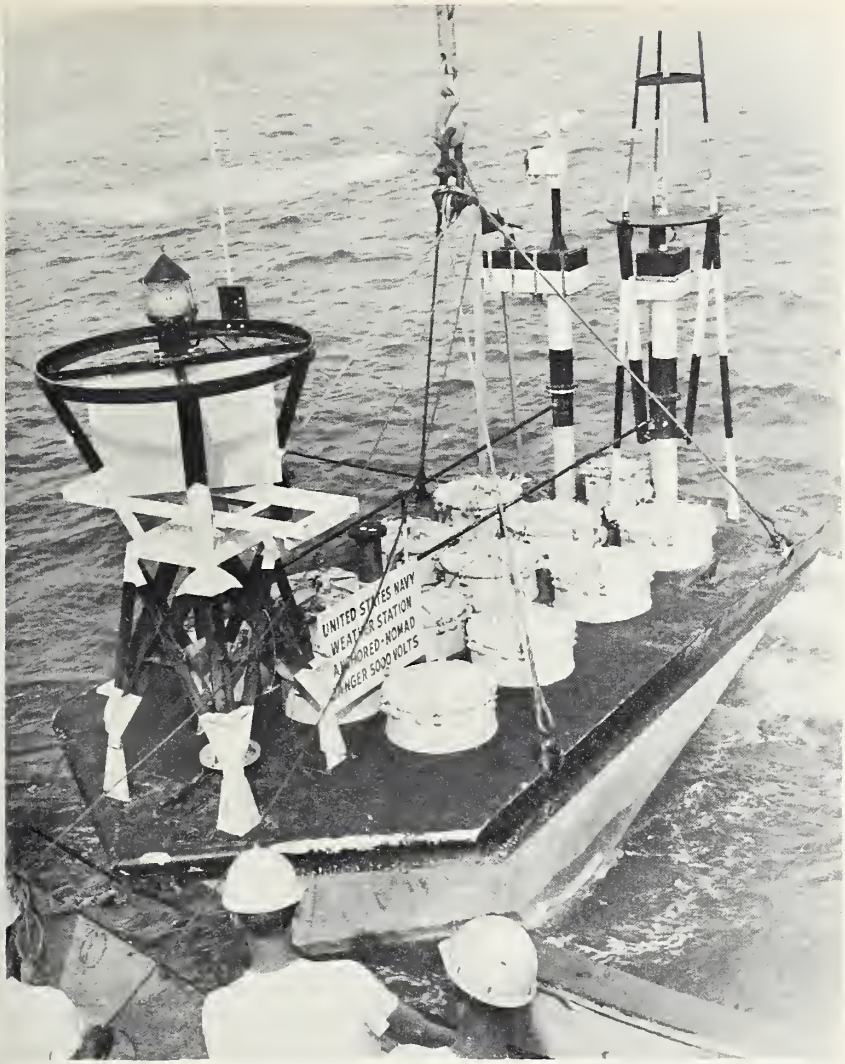
The accomplishments described below are intended primarily to provide a general insight into the type and variety of activities IAT undertakes for other agencies. Many of the projects discussed under other categories in the IAT section were also undertaken for other agencies.

Aid to Patent Office.—A simulation of Patent Office policy changes was developed and tested to estimate future waiting periods and workloads. Also, a systems analysis was developed in support of the Patent Office Program Memorandum, and a study was completed of the extent to which judgmental flexibility is used in the patent examination process.

Floating Weather Station Uses Nuclear Power.—Another in the series of NOMAD (*N*avy *O*ceanographic *M*eteorological *A*utomatic *D*evice) weather stations developed for the Bureau of Naval Weapons, is now anchored to supply meteorological data from the Gulf of Mexico. Power for its transmissions comes from batteries kept charged by a nuclear generator. Data from NOMAD will help ships and aircraft to evade storms and allow people on shore to prepare for them.

Computer Center Aids Federal Agencies.—The NBS Center for Computer Sciences and Technology was designated to conduct research for and render technical services to the Administrator of General Services and to other Government agencies on request. This work is designed to aid in improving cost effectiveness in the conduction of Federal programs through the selection, acquisition, and effective utilization of automatic data processing equipment.

Computer Center Studies Recreation Facilities.—As part of a nationwide plan for outdoor recreation, a formatted data file of information concerning approximately 45,000 existing and potential recreation areas in the United States was created. Tabulations were made from the file to highlight deficiencies and potential areas of expansion as aids to the development by the Bureau of Outdoor Recreation of a comprehensive plan to meet the recreational needs of the Nation.



Navy weather data station NOMAD, developed at NBS, is shown being anchored in the Gulf of Mexico.

Aid to Army Military Effectiveness.—NBS is assisting the U.S. Army Electronic Command in the evaluation of a wide range of display devices and techniques—such as charts, maps, and drawings—used for military purposes. Methods will also be developed for making the displays compatible with a central computer complex, such as the NBS-developed MAGIC computer. This system can take pictorial material into its memory and reproduce it on a screen. Areas in which ADP play an important part include fire control, intelligence, administration, logistics, and operations.

Display requirements range from individual field devices to large-scale wall-size systems.

Blood Flow Sensor Developed.—A sensor has been developed for the National Institutes of Health which indicates rate of blood flow and requires that only one small electrode be inserted into the blood stream. The system makes use of a newly discovered relationship between blood flow and electrical conductivity. Medical scientists have long wanted to be able to measure blood flow in the human body without having to use operative techniques.

Investigation of Chinese Language Characters.—Work continued on the linguistic study of the structure of Chinese characters under NBS and Rome Air Development Center support. The research has been in two closely related areas: (1) Grammar construction, through which many of the two-dimensional formation processes underlying the characters have been formalized, and (2) graphical information processing, in which algorithms associated with some of the above-mentioned formalized processes have been implemented as programs for the NBS MAGIC computer. It is expected that research of this type will lead to a foundation for the eventual direct machine-handling of Chinese characters in particular, and of two-dimensional information in general.

EXPLORATORY RESEARCH

A portion of the Institute's effort is devoted to exploration of technical areas broadly related to its other programs, but where direct relevance to those programs becomes apparent only after careful study.

Role of the Federal Government in Technological Forecasting—In February 1965, an interagency task group was formed, reporting to the President's Committee on Manpower and to the Commission on Technology Automation and Economic Growth. Four of the six members were NBS staff and Donald Schon, director of the NBS Institute for Applied Technology, chaired the group. The purpose was to investigate the current and the possible future role of technological forecasting in the Federal Government, with particular emphasis on the relevance of technological forecasting to manpower problems, policies and programs.

Development of New Building Systems.—A contract was received from the General Services Administration to study the feasibility of using a portion of the GSA building construction program to help private industry develop new or improved building systems. The goal of this joint effort is to find one or more

building types which lend themselves to a program for developing new building subsystems. Any economic advantage to the Nation's building industry will be as important as the benefits gained by the General Services Administration in its own projects. These new systems should provide a source of advanced technology for both government and non-government construction programs.

AUTOMATIC DATA PROCESSING

The NBS Center for Computer Sciences and Technology operates to fulfill responsibilities given to the Secretary of Commerce by the Bureau of the Budget. These responsibilities fall in four major categories: ADP standards, research, advisory and consultative services and computer services.

ADP Standards

Project Nomination.—In this phase it is necessary to determine the need, define the scope and collect all available information that would relate to a specific proposed standard. Major current projects in this area include: glossary of ADP terms, data interchange codes, magnetic tape measurement techniques, FORTRAN standard reference, COBOL programming language.

Standards Development.—Here it is necessary to prepare a working draft, resolve controversy over alternatives, coordinate with involved manufacturers, suppliers, Federal Government users, the Bureau of the Budget, and BOB's ADP Advisory Council and Interagency Committee on ADP, and then develop a consensus. Projects in this phase were: standard character codes for information interchange, standard perforated tape code for information interchange.

Recommendation.—It then remains to make a final draft and, together with historical background and justification materials, forward through the Secretary of Commerce to the Bureau of the Budget.

Voluntary Standards.—An important function of the Center is support for national and international voluntary standards work. Eleven significant standards have been promulgated or revised through fiscal year 1966.

Research

Communications Network Analysis.—NBS conducted a study for the Defense Communications Agency to develop computer-based techniques for identifying relatively "minor" network ele-

ments whose disablement would be disproportionately damaging to overall communications network capability.

Man-Machine Investigation.—Methods and concepts of information display, manipulation, search and presentation with on-line computer systems were developed. Included was a test-bed facility for use by other Federal agencies to become familiar with features of available equipment in order to express reqirements for their own in-house applications when procuring such systems.

Geophysical Data Logging.—NBS computer specialists collected, edited and disseminated statistics on background noise of interest to geophysicists and the nuclear detection community.

Models of Information Systems and Information Processes.—General and efficient methods were developed for the aggregation and disaggregation of resource flow networks and models of technological and input-output variety, which draw heavily on current statistical information systems.

Consultative and Advisory Services

Radiological Data Processing System.—The Radiological Health Laboratory, Public Health Service, is charged with the responsibility of processing radiological data reported from a national network. Its Surveillance System collects data on the concentration of various radioactive nuclides in pasteurized milk, human bones, air, precipitation, etc. The Center cooperated with the Radiological Health Laboratory to revamp their information processing systems and to provide improved reporting capability, faster processing, faster retrieval of needed information, with minimal programming requirements.

HEW Automatic Data Processing Requirements Study.—This management organization study, at the request of HEW through the Bureau of the Budget, was the first made under the joint aegis of the Bureau of the Budget, the General Services Administration, and the Department of Commerce. It is anticipated that the study's recommendations will improve HEW's organizational structure and management control for automatic data processing services. The study could be used as a "pattern" by some other Federal agencies, thus contributing to an overall improvement of cost-effectiveness in the Government's use of computers.

Department of Labor Data Systems Studies.—To assist the Department of Labor in getting full value for investments in major contracted systems studies, the Center assigned a staff member to help the Office of the Secretary of Labor monitor the performance of various contractors. Included in these studies is a five-year master plan for orderly development of information

systems making effective use of computers for the Department of Labor.

Computer Services

Department of State.—A series of programs, tabulations and special analyses of data for Department of State personnel was undertaken. The project had two major objectives: first, to provide a basis for manpower planning in terms of how many officers are needed, and with what skills; secondly, to provide data generated in manpower studies for use in career management programs.

NBS Administrative Operations.—Development of a comprehensive system of COBOL programs was undertaken to support automation of various NBS administrative operations. These include payroll, personnel, accounting, budget and management. The entire project will, in its final version, provide a fully integrated resource planning and management system.

Scientific Computing Support.—Approximately 33 percent of Computer Services machine time consists of scientific computing work in support of other technical divisions at NBS. Programming for these tasks is generally performed by the originating group. On the average, there are approximately 240 separate computer runs of this type per week, with a median time duration between two and three minutes per run. The number of computer runs in an average week for both NBS and non-NBS users is over 700.

APPENDIXES

ORGANIZATION OF THE NATIONAL BUREAU OF STANDARDS*

The Bureau is headed by a Director who is appointed with the advice and consent of the Senate. The Director is assisted in the overall management of the Bureau by a Deputy Director. In addition, there are three Associate Directors and an Executive Officer for Boulder (Colorado) Support who are responsible for the planning and operation of various technical and administrative management services in support of the Bureau's technical programs.

Technical program activities are conducted in organizational units known generally as Institutes. Each is headed by an Institute Director who is responsible for the development and direction of research programs and central national services essential to the fulfillment of a broad segment of the Bureau's mission. These major organizational units are

(1) The Institute for Basic Standards, which includes 13 divisions (4 in Boulder, Colo.), each serving a classical subject matter area of science and engineering;

(2) The Institute for Material Research, which consists of 7 divisions (1 in Boulder, Colo.), organized primarily by technical field; and

(3) The Institute for Applied Technology, which includes 16 industry-oriented divisions.

The Central Radio Propagation Laboratory, comprising a series of four divisions, was transferred to the Commerce Department's Environmental Science Services Administration on October 11, 1965.

DIRECTOR
ALLEN V. ASTIN

DEPUTY DIRECTOR
I. C. SCHOONOVER

*As of June 30, 1966

Assistant to the Deputy Director
P. H. KRATZ

OFFICE OF THE DIRECTOR

Assistants to the Director
G. E. AUMAN
C. N. COATES

Legal Advisor
A. J. FARRAR

Office of Industrial Services
R. L. STERN

Office of Public Information
A. V. GENTILINI

Associate Director for Academic Liaison
S. SILVERMAN

Office of Engineering Standards Liaison and Analysis
G. S. GORDON

Office for Program Development and Evaluation
Vacant

SENIOR RESEARCH FELLOWS

C. EISENHART
K. SHULER
S. N. ALEXANDER

OFFICE OF ASSOCIATE DIRECTOR FOR ADMINISTRATION

R. S. WALLEIGH

Assistant to the Associate Director
P. H. SCHRADER

Patent Advisor
D. ROBBINS

Accounting	J. P. MENZER, *Acting*
Administrative Services	G. W. KNOX
Budget and Management	J. E. SKILLINGTON
Internal Audit	H. F. WHITTINGTON
Personnel	G. R. PORTER
Plant	M. B. GOETZ, *Acting*
Supply	G. B. KEFOVER

EXECUTIVE OFFICER FOR BOULDER SUPPORT *

S. W. J. WELCH

Administrative Services	B. F. BETTS, *Acting*
Shops	R. S. PERRILL
Plant	E. A. YUZWIAK

*Located in Boulder, Colo.

OFFICE OF ASSOCIATE DIRECTOR FOR TECHNICAL SUPPORT

Vacant

Coordinator of Special International Programs	L. L. MARTON
Office of Technical Information and Publications	W. R. TILLEY
Research Information	Vacant
Office of Radiation Safety	A. SCHWEBEL, *Acting*
Instrument Shops	F. P. BROWN
Measurement Engineering	G. F. MONTGOMERY

INSTITUTE FOR BASIC STANDARDS

Director
R. D. HUNTOON

Deputy Director
M. B. WALLENSTEIN

Deputy Director for Radio Standards *
J. M. RICHARDSON

Associate Director for Measurement Services
W. A. WILDHACK

Assistant to the Director
H. L. MASON

Office of Standard Reference Data ..... E. L. Brady
- Nuclear Properties
- Atomic and Molecular Properties
- Solid State Properties
- Thermodynamic and Transport Properties
- Chemical Kinetics Data
- Colloid and Surface Properties
- Mechanical Properties
- Information Systems Design and Research
- Information Services Operation

Applied Mathematics ..... E. W. Cannon
- Numerical Analysis
- Statistical Engineering
- Mathematical Physics
- Operations Research

Electricity ..... C. H. Page
- Resistance & Reactance
- Electrochemistry
- Electrical Instruments
- Magnetic Measurements
- High Voltage
- Absolute Electrical Measurements

Metrology ..... A. G. McNish
- Photometry and Colorimetry
- Refractometry
- Photographic Research
- Length
- Engineering Metrology
- Mass and Volume

Mechanics ..... B. L. Wilson
- Sound
- Engineering Mechanics
- Rheology
- Mechanical Measurements Branch
  - Pressure Measurements
- Fluid Mechanics Branch
  - Fluid Meters

*Located in Boulder, Colo.

Vacuum Measurements
Vibration Measurements
Humidity Measurements
Hydraulics
Aerodynamics

Heat ..... R. P. Hudson
- Heat Measurements
- Cryogenic Physics
- Equation of State
- Statistical Physics
- Temperature
- Radiation Thermometry

Atomic Physics ..... K. G. Kessler
- Spectroscopy
- Infrared and Microwave Spectroscopy
- Far Ultraviolet Physics
- Electron Physics
- Atomic Physics
- Plasma Spectroscopy

Physical Chemistry ..... R. E. Ferguson
- Thermochemistry
- Surface Chemistry
- Elementary Processes
- Mass Spectrometry
- Photo Chemistry
- Radiation Chemistry

Laboratory Astrophysics* ..... L. M. Branscomb

Radiation Physics ..... H. W. Koch
- Radiation Theory
- Radiological Physics Branch
  - X-ray Physics
  - Dosimetry
  - X-ray Standards
- Nuclear Physics Branch
  - Radioactivity
  - Neutron Physics
  - Photonuclear Physics
  - Nuclear Spectroscopy
- Accelerator Branch
  - Accelerator Engineering
  - Radiation Physics Instrumentation
  - Accelerator Physics

Radio Standards Laboratory* ..... J. M. Richardson

Radio Standards Physics* ..... Y. Beers
- Frequency-Time Dissemination Res.
- Frequency-Time Broadcast Services
- Radio and Microwave Materials
- Atomic Frequency & Time Stds.
- Quantum Electronics
- Radio Plasma

Radio Standards Engineering* ..... H. M. Altschuler
- HF Calibration Services
- HF Electrical Standards
- HF Impedance Standards
- Microwave Calibration Services
- Microwave Circuit Standards
- Electromagnetic Fields Standards

INSTITUTE FOR MATERIALS RESEARCH

Director
G. K. Teal

Deputy Director
H. C. Allen, Jr.

Assistant to the Director
H. E. Sorrows

Materials Evaluation Laboratory ..... R. B. Hobbs
- Materials Evaluation and Testing
- Procurement Systems
- Evaluation Criteria
- Performance Research

Office of Standard Reference Materials ..... W. W. Meinke

Analytical Chemistry ..... W. W. Meinke

*Located in Boulder, Colo.

Radiochemical Analysis
Spectrochemical Analysis
Electrochemical Analysis
Analytical Coordination Chemistry
Microchemical Analysis
Analytical Mass Spectrometry
Organic Chemistry
Activation Analysis
Separation and Purification

Polymers ..... J. D. Hoffman
Polymer Solutions
Polymer Chemistry
Polymer Physics
Molecular Properties
Dental Research
Polymer Characterization

Metallurgy ..... M. R. Meyerson, Acting
Engineering Metallurgy
Alloy Physics
Lattice Defects and Microstructures
Corrosion
Metal Physics
Electrolysis and Metal Deposition
Crystallization of Metals

Inorganic Materials ..... E. Ambler
Inorganic Chemistry
Inorganic Glass
High Temperature Chemistry
Crystal Chemistry
Physical Properties
Crystallography
Solid State Physics

Reactor Radiations ..... C. O. Muehlhause

Cryogenics* ..... B. W. Birmingham
Cryogenic Technical Services
Cryogenic Data Center
Cryogenic Properties of Solids
Properties of Cryogenic Fluids
Cryogenic Systems
Cryogenic Metrology
Cryogenic Fluid Transport Processes

INSTITUTE FOR APPLIED TECHNOLOGY

Director
J. P. EBERHARD†

Deputy Director
L. M. KUSHNER†

Manager, Engineering Standards ..... M. W. Jensen

Office of Engineering Standards Services ..... D. R. Mackay

Office of Weights and Measures ..... M. W. Jensen

Office of Invention and Innovation ..... D. V. DeSimone
Innovation Studies and Analyses
Invention Programs

Clearinghouse for Federal Scientific and Technical Information ..... B. M. Fry
Document Reproduction and Distribution Branch
Automated Systems and Services Branch
Publications and Customer Relations Branch
Administrative Services
Joint Publications Research Service
Document Processing Branch
Technology Review Branch

Building Technology ..... A. A. Bates
Structures
Fire Research
Environmental Engineering
Materials and Composites
Codes and Standards

* Located in Boulder, Colo.
† As of July 1, 1966.

Electronic Instrumentation ..... M. G. Domsitz
- Engineering Electronics
- Basic Instrumentation
- Electron Devices

Textile and Apparel Technology Center ..... F. C. Brenner
- Contract Research Program
- Technical Support Program

Technical Analysis Division ..... W. E. Cushen
- Northeast Corridor Transportation Simulation and Data Bank
- Innovation Studies
- Economic Systems Studies-Models
- Benefit-Cost Studies
- Service Studies
- Economic Benefit Studies

Center for Computer Sciences and Technology ..... N. J. Ream

Office for Information Processing standards ..... J. Wegstein, Acting

Technical Information Exchange ..... M. R. Fox, Acting

Computer Services — I. V. Voltin

Management Applications Planning — H. Gammon, Acting

Systems Research and Development — E. Marden, Acting

Information Processing Technology — J. Nigro, Acting

Information Sciences — Vacant

FIELD ESTABLISHMENTS

Institute for Basic Standards

Metrology Division Field Station:
- Visual Landing Aids Field Laboratory — Arcata, Calif.

Institute for Applied Technology

Office of Weights and Measures Field Stations:
- Master Railway Track Scale Depot — Clearing, Ill.

Building Research Field Stations:
- Materials Testing Laboratories — Denver, Colo.; Seattle, Wash.

Radio Standards Laboratory Field Stations:
- Standard Frequency Station WWV — Greenbelt, Md.
- Standard Frequency Station WWVL-WWVB — Fort Collins, Colo.
- Standard Frequency Station WWVH — Maui, Hawaii

Laboratory Astrophysics Division Field Station:
- Poor Man's Relief Mine, Four-Mile Canyon — Boulder, Colo.

SUMMARY OF NBS STAFF AS OF JUNE 30, 1966

	Washington	Boulder	Total
Total permanent staff	2,940	629	3,569
Other staff**	335	106	441
Total on rolls	3,275	735	4,010
Research associates & guest workers	104	12	116
Total on rolls at NBS	3,379	747	4,126

Professional staff***			
Physicists	434	113	547
Chemists	290	10	300
Engineers	173	99	272
Mathematicians	52	11	63
Other	133	3	136
Total professional staff	1,082	236	1,318

**WAE, consultants, students, teachers, postdoctoral fellows, and temporary-limited employees.

***Full-time permanent (excludes any under **).

FINANCIAL DATA FOR FISCAL YEAR 1966

Program and Source of Financing	*Obligations Incurred In Thousands of Dollars (Rounded)*
Supported by NBS Appropriations	
Operating Programs:	
Research and Technical Services	$28,665
Civilian Industrial Technology	439
Special Foreign Currency Program	498
Construction and Facilities Programs:	
Plant and Facilities	2,654
Construction of Facilities	10,970
Total Obligations, NBS Appropriations	43,226
Supported by Other Funds*	
From Other Federal Agencies	20,104
From Other Sources	3,692
Total Obligations, Other Funds	23,796
Total Program	67,022

*Work supported by other funds consists of research and development programs for other Government agencies; consultative, advisory, and technical services, the performance of various tests and calibrations, and the manufacture and sale of standard reference materials for other Government agencies and the public.

ADVISORY COMMITTEES

STATUTORY VISITING COMMITTEE

Reports annually to Secretary of Commerce on NBS activities. Dates indicate expiration of appointment.

Dr. E. R. Piore, Vice President, Research & Engineering, International Business Machines Corporation (1967), Chairman

Dr. Frederick Seitz, President, National Academy of Sciences (1966)
Dr. Elmer W. Engstrom, President, Radio Corporation of America (1968)
Dr. Paul C. Cross, President, Mellon Institute (1969)
Prof. Norman F. Ramsey, Department of Physics, Harvard University (1970)

TECHNICAL ADVISORY PANELS

During the past year the National Academy of Sciences-National Research Council continued to provide technical advice to the Bureau. Twenty panels were in existence, and one (Information Technology) was abolished. Several new panels were created because of new responsibilities laid upon the Bureau and because of certain reorganization within the Institutes. Of the twenty panels, twelve met at least once, and the Textile and Apparel Advisory panel met four times.

Institute for Basic Standards

Dr. R. D. Huntoon, Director

Advisory Panel to Applied Mathematics Division

Prof. Francis J. Anscombe, Yale University, Chairman
Prof. Charles R. DePrima, California Institute of Technology
Prof. Joaquin B. Diaz, University of Maryland
Dr. Ralph E. Gomory, International Business Machines Corp.
Dr. J. P. LaSalle, Research Institute for Advanced Studies
Dr. J. Barkley Rosser, University of Wisconsin
Prof. John Todd, California Institute of Technology
Prof. John W. Tukey, Princeton University

Advisory Panel to Electricity Division

Dr. William G. Amey, Leeds & Northrup Company, Chairman
Dr. Richard M. Bozorth, International Business Machines Corp.
Mr. Ivan. G. Easton, General Radio Company
Prof. Raymond M. Fuoss, Yale University
Dean R. B. Lindsay, Brown University
Mr. E. C. Starr, U. S. Department of the Interior
Prof. M. B. Stout, University of Michigan
Prof. John G. Trump, Massachusetts Institute of Technology

Advisory Panel to Metrology Division

Dr. J. H. Webb, Eastman Kodak Company, Chairman
Prof. Isay A. Balinkin, University of Cincinnati
Dr. Alsoph H. Corwin, The Johns Hopkins University
Mr. C. L. Crouch, Illuminating Engineering Society

Mr. A. M. Dexter, Bausch & Lomb Incorporated
Dr. Robert E. Hopkins, University of Rochester
Mr. Louis Polk, Dayton, Ohio
Mr. Eric J. Schneider, Engis Equipment Company
Prof. John Strong, The Johns Hopkins University

Advisory Panel to Mechanics Division
Prof. S. R. Beitler, American Society of Mechanical Engineering, Chairman
Prof. Lynn S. Beedle, Lehigh University
Dr. B. B. Dayton, Consolidated Vacuum Corporation
Prof. Cyril M. Harris, The Columbia University
Prof. Arthur T. Ippen, Massachusetts Institute of Technology
Dr. Harry F. Olson, Radio Corporation of America
Dr. M. E. Shank, Pratt & Whitney Aircraft
Prof. R. S. Rivlin, Brown University

Advisory Panel to Heat Division
Dr. Charles F. Squire, Texas A&M University, Chairman
Prof. Howard W. Emmons, Harvard University
Prof. H. R. Griem, University of Maryland
Dr. Paul G. Klemens, Westinghouse Research Laboratories
Prof. Robert S. Mulliken, The Florida State University
Prof. John Ross, Brown University
Prof. Clayton A. Swenson, Iowa State University
Prof. Edgar F. Westrum, Jr., University of Michigan

Advisory Panel to Atomic Physics Division
Prof. W. R. Bennett, Jr., Yale University, Chairman
Prof. R. Grant Athay, University of Colorado
Dr. Wade L. Fite, University of Pittsburgh
Dr. Leo Goldberg, Harvard College Observatory
Prof. Gabriel Weinreich, University of Michigan

Advisory Panel to Physical Chemistry Division
Dr. Henry Eyring, University of Utah, Chairman
Prof. Robert Gomer, The University of Chicago
Dr. Joseph O. Hirschfelder, University of Wisconsin
Dr. Max S. Matheson, Argonne National Laboratory
Dr. Daniel R. Stull, The Dow Chemical Company
Prof. Harold S. Johnston, University of California
Dr. Norman D. Coggeshall, Gulf Research & Development Company

Advisory Panel to Laboratory Astrophysics
Dr. Leo Goldberg, Harvard College Observatory, Chairman
Dr. Wade L. Fite, University of Pittsburgh
Prof. W. R. Bennett, Jr., Yale University

Dr. Arthur Kantrowitz, Everett Research Laboratory
Dr. A. Keith Pierce, Kitt Peak National Observatory
Dr. O. C. Wilson, California Institute of Technology

Advisory Panel to Radiation Physics Division

Dr. Robley D. Evans, Massachusetts Institute of Technology, Chairman
Dr. John S. Blair, University of Washington
Mr. Casimer J. Borkowski, Oak Ridge National Laboratory
Dr. Peter T. Demos, Massachusetts Institute of Technology
Dr. John S. Laughlin, Sloan-Kettering Institute for Cancer Research
Dr. Marshall R. Cleland, Radiation Dynamics, Inc.
Dr. Vance L. Sailor, Brookhaven National Laboratory
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Mr. A. R. Lytle, National Academy of Sciences-National Research Council
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Prof. Hoyt C. Hottel, Massachusetts Institute of Technology
Mr. Joseph H. Newman, Tishman Research Corporation
Mr. Alwin B. Newton, Borg-Warner Corporation
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Mr. J. A. Caffiaux, Electronic Industries Association
Mr. Ivan G. Easton, General Radio Company
Mr. Edward S. Hill, Texas Instruments Incorporated
Dr. C. H. Hoffman, Illinois Institute of Technology
Dr. Robert Jeffries, Data Control Systems Inc.
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Dr. Russell H. Lyddane, General Electric Company
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Mr. Peter R. Perino, Statham Instruments, Inc.
Dr. Robert L. Pritchard, Stanford Electronics Laboratories
Mr. Samuel H. Watson, Radio Corporation of America
Dr. Richard C. Webb, Colorado Instruments Inc.
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Mr. William J. Bank, Jonbil Manufacturing Co., Inc.
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Dr. Frank Fisher, National Academy of Sciences
Mr. J. B. Goldberg, New York, N. Y.
Mr. George Perkel, Textile Workers Union of America
Mr. Kurt Salmon, Kurt Salmon Associates, Inc.
Mr. Horace A. Secrist, The Kendall Company
Mr. Victor F. Sepavich, Crompton & Knowles Corporation
Mr. Levon M. Yacubian, Barre Wool Combing Co., Ltd.

AWARDS AND HONORS

Recognition of the Bureau's contributions to science and technology often takes the form of awards and honors from Government, academic, professional, and industrial groups. The following list reflects such recognition bestowed on Bureau staff members during fiscal year 1966:

Recipient	*Award*
Allen, Harry	Samuel Wesley Stratton Award
Astin, Allen V.	Elected Vice President for Physics and Chairman of the Section Committee on Physics of the American Association for the Advancement of Science for 1966
Codling, Keith	Achievement Award from the Washington Academy of Sciences
Hague, John L.	ANACHEM Award from Association of Analytical Chemists
Hamer, Walter J.	Honorary Doctor of Science degree from Juniata College, Huntingdon, Pa.
Judd, Deane B.	Samuel Wesley Stratton Award
Kline, Gordon M.	Edward B. Rosa Award
Kloss, Kenneth E.	National Capital Award by D. C. Council of Engineering and Architectural Societies and Washington Academy of Sciences
Madden, Robert P.	Achievement Award from the Washington Academy of Sciences
Milligan, Dolphus E.	Professor Arturo Miolati Prize from the University of Padua, Italy
Rosenblatt, Joan R.	Achievement Award from the Washington Acadamy of Sciences
Sitterly, Charlotte Moore	Civil Service Career Award
Sugar, Jack	Fulbright grant
Taylor, Lauriston S.	Edward B. Rosa Award

Department of Commerce Exceptional Service Awards

(Gold Medal)

Technical Area	*Recipient*
Herbstreit, Jack W.	Radio properties of the atmosphere affecting precision missile tracking and guidance systems.
Leiss, James E.	Linear accelerator design and instrumentation
Newman, Morris	Computer science and technol-

	ogy and distinguished authorship
Group Award:	
Roder, Hans M.	
Weber, Lloyd A.	
Diller, Dwain E.	Properties of parahydrogen
Corruccini, Robert J.	
Younglove, Benny A.	
Goodwin, Robert D.	
Group Award:	Science of aeronomy through
Schmeltekopf, Arthur L.	laboratory work on the fundamental atomic and molecular
Ferguson, Eldon E.	processes pertinent to the upper
Fehsenfeld, Fred C.	atmosphere

Department of Commerce Meritorious Service Awards

(Silver Medal)

Bozman, William R.	Application of computer techniques to the publication of scientific data
Danos, Michael	Theoretical physics and nuclear theory
Ginnings, Defoe C.	Calorimetry including design, techniques, and application to measurements
Goldman, Alan J.	Commerce Department programs and meritorious authorship in the field of operations research
Hudson, Paul A.	Development and construction of the Nation's standards for cw and pulse power and pulse voltage
Irwin, Lafayette K.	Administrative direction and creative engineering design in relocation of Engineering Mechanics Section
Lee, Richard D.	Accuracy of realizing the International Practical Temperature Scale
Manning, John R.	Solid state theory
Pelander, Carl E.	Support services for the Laboratory Astrophysics Division at JILA
Pfaff, Philip, Jr.	Mechanical design contributions

	to major scientific programs of NBS
Plumb, Harmon H.	Temperature standards through development of primary and secondary cryogenic thermometers
Pummer, Walter J.	Chemical research on aromatic fluorocarbons and polymers
Rosenstock, Henry M.	Molecular ionization processes
Group Award:	
Gillilland, Kitt E. Mielenz, Klaus D. Nefflen, Karl F. Stephens, Robert B.	Application of continuous-wave gas laser to length metrology

Department of Commerce Superior Service Award
(Bronze Medal)

Bergh, Maurice	Support services for Cryogenics Division
Cuthill, John R.	Design and construction of an electron probe microanalyzer
Katahara, Sadami	Performance as Chief of NBS field station, Maui, Hawaii
Mend, Hans	Scientific instruments
Shultz, James I.	Standard reference materials for Steel Industry
Weaver, Frank D.	Electrical metrology, measurement systems and calibration services
Williams, Geneva F.	Calibration and research operations of the Thermometry Laboratory
Group Award:	
Bean, B. Leonard Blaine, Raymond L. Brookhyser, Robert R. Corah, Harold J. DeFore, Martin R. Evans, Donald N. Foster, Bruce E. Marek, Otto C. Stiller, Gerald R. Watton, George Winblade, Frank N.	Management and operation of the cement testing program and its related standardization activities

EDUCATION, TRAINING, AND UNIVERSITY LIAISON

A broad employee program, implemented primarily through the NBS Graduate School and non-government educational and training facilities, is available to all staff members. The program covers education through postdoctoral research and is offered at both the Boulder and Gaithersburg Laboratories. The primary objectives—to increase employee efficiency in assigned duties and to prepare systematically for increased responsibilities—are to an increasing extent encompassing the management and supervisory areas as well as the traditional areas of science and technology.

The NBS Graduate School

The NBS Graduate School curriculum includes graduate and undergraduate courses in the physical sciences, mathematics, and certain branches of engineering. A series of scientific colloquia and seminars are led by research leaders from the Bureau and from other research centers and, in addition, general staff development courses, such as scientific German, practical metallurgy, and mathematical symbolism and terminology are offered. Educational counseling is available, and employees may receive thesis accreditation for research done at the Bureau. In addition, a Technician Career Program, for subprofessional laboratory personnel, offers a series of in-hours courses on the fundamentals of science and mathematics. Surveys periodically redetermine course offerings and keep the program in step with the changes and variations in educational requirements.

An interesting variation of the basic theme finds the Graduate Program at Boulder associated with the University of Colorado in a Joint-Course program and Adjunct Professor Plan. Various graduate departments of the NBS Graduate School and the University offer courses which mutually benefit the Government and the University.

Since the establishment of the educational program in 1908, 42 universities have awarded 337 graduate degrees based partly on credits obtained for thesis work carried on under the NBS Graduate School Program.

Non-Government Education

Non-government education, authorized by the Government Employees Training Act of 1958, falls into three categories—full-time (3 to 12 months) postdoctoral study and research assignments at universities and research centers, full-time (less than 3 months) attendance at institutes, seminars, short concentrated

courses and workshops and part-time, job-related academic courses at local educational institutions.

Four hundred and fifty staff members at Washington and Boulder were trained through non-government facilities last year; six career scientists were selected for full-time research assignments at universities and research centers Participants in approved full-time training programs receive full salary and expenses, including tuition, fees, travel and per diem, as well as transportation of family and household effects.

Short concentrated courses and training programs at universities and in industry were attended by 146 staff members. Two hundred and ninety-eight employees, mostly from technical divisions, attended job-related courses at local educational facilities.

Interagency Courses

The interagency series of courses is another important area of government-sponsored programs. Two hundred and sixty-five Bureau employees participated in a wide range of special courses with a sizeable number in the supervisory-management fields. In addition, the Commerce Department offers an intradepartment Science and Technology Fellowship Program. Last year nine NBS employees went to other Bureaus in the Department while seven were assigned to NBS.

Student Trainee Programs

Each year a student trainee summer program is held for college and graduate students majoring in the physical sciences, mathematics, and certain branches of engineering. At this time an integrated work-study plan including lectures, tours, demonstrations, supervised laboratory assignments, and professional counseling is conducted. The program acquaints young people interested in career scientific research opportunities with the work of NBS. One hundred and eight students worked in this program last summer. Other summer programs include the assignment of high school science teachers to the Bureau under National Science Foundation sponsorship and American University administration. Last year 16 physics and chemistry teachers worked in NBS laboratories. One hundred and ten students, primarily at the high school level, had summer assignments at Washington and Boulder under the Youth Opportunity Program for young people qualifying on the basis of economic need. In addition to these student programs, 17 college faculty members were employed for the summer in NBS laboratories.

Postdoctoral Programs

In collaboration with the National Research Council, the National Bureau of Standards offers postdoctoral resident research

associateships. Selection covers young scientists promising to become creative leaders in the various branches of the physical and mathematical sciences. While improving themselves professionally, opportunities are open to increase scientific knowledge by developing new approaches and laboratory skills.

Sabbatical Opportunities

Distinguished scientists are encouraged to spend their sabbatical years, summer vacations, or other extended periods at the Bureau. These visiting scientists increase the Bureau's ties with the academic community and provide a continuing influx of new ideas into the Washington and Boulder programs.

PUBLICATIONS*

PUBLICATIONS IN THE BUREAU'S SERIES

During the year NBS publications totaled 1,107 published papers and documents.

Of the formal publications, 189 appeared in the Journal of Research, and 628 in the journals of professional and scientific societies. Also, 188 summary articles were presented in the Bureau's monthly Technical News Bulletin.

In the nonperiodical series, 102 documents were published: 7 in the Monograph series, 3 in the Handbook series, 17 in the Miscellaneous Publication series, 61 in the Technical Notes series, 8 Commercial Standards, 1 National Standard Reference Data Series, 4 Building Science Series, and 1 Simplified Practice Recommendation.

Journal of Research. Contains full research papers, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Advances in measurement standards and techniques . . . physical constants . . . properties of materials . . . instrumentation . . . radio propagation

The Journal was published in four separate sections . . .

A. Physics and Chemistry, issued six times a year. Annual subscription: Domestic, $5; foreign, $6.75; single copy, $1.00.

B. Mathematics and Mathematical Physics, issued quarterly.

*Publications for which a price is indicated are available by purchase from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (foreign postage, one-fourth additional). The NBS nonperiodical series are also available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151. Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

Annual subscription: Domestic, $2.25; foreign, $2.75; single copy, 75 cents.

C. Engineering and Instrumentation, issued quarterly. Annual subscription: Domestic $2.75; foreign, $3.50; single copy, 75 cents.

D. Radio Science (formerly Radio Propagation), issued monthly Annual subscription: Domestic, $9; foreign, $11.50; single copy, $1.00. Beginning with January 1966 this publication was transferred to the Environmental Science Services Administration, Boulder, Colorado, it is still published monthly and known as Radio Science at the same subscription rates.

Volume 69A (Phys. and Chem.), No. 4 (July-August 1965)

Correlation of successive atomic steps in crystals by relaxation mode analysis. A. D. Franklin.

Reduction of crystallographic point groups to subgroups by homogeneous stress. H. S. Peiser and J. B. Wachtman, Jr.

Effect of hydrostatic pressure on the refractive indices of some solids. R. M. Waxler and C. E. Weir.

Crystallization kinetics and polymorphic transformations in polybutene–1. J. Powers, J. D. Hoffman, J. J. Weeks, and F. A. Quinn, Jr.

Compliance-time-temperature relationships from indentation measurements on a pure-gum rubber vulcanizate. F. L. Roth, G. W. Bullman, and L. A. Wood.

Distribution function of the end-to-end distances of linear polymers with excluded volume effects J. Mazur.

An additivity rule for the vapor pressure lowering of aqueous solutions. R. A. Robinson and V. E. Bower.

Franck-Condon factors to high vibrational quantum numbers V: O_2 band systems. R. W. Nicholls.

An absolute temperature scale from 4 °K to 20 °K determined from measurements with an acoustical thermometer. H. H. Plumb and G. Cataland.

Volume 69A (Phys. and Chem.), No. 5 (Sept.-Oct. 1965)

Current research on preservation of archival records on silver-gelatin type microfilm in roll form. C. S. McCamy and C. I. Pope.

Franck-Condon factors to high quantum numbers VI: C_2 band systems. R. W. Nicholls.

Matrices of spin-orbit interaction in the electron configurations p^2d and p^4d. J. L. Tech and R. H. Garstang.

Heat of formation of calcium aluminate tricarbonate at 25 °C. H. A. Berman.

Vapor pressure and heat of sublimation of tungsten. R. Szwarc, E. R. Plante, and J. J. Diamond.

Heat capacity and enthalpy measurements on aluminum carbide (Al_4C_3) from 15 to 1173 °K. Thermodynamic properties from 0 to 2000 °K. G. T. Furukawa, T. B. Douglas, W. G. Saba, and A. C. Victor.

Properties of aqueous mixtures of pure salts: thermodynamics of the ternary system water-potassium chloride-barium chloride at 25 °C. R. A. Robinson and V. E. Bower.

A wide-range (up to 10^{10} P) rotating cylinder viscometer. Albert Napolitano, P. B. Macedo, and E. G. Hawkins.

Internal friction in ZrO_2 containing CaO. J. B. Wachtman, Jr., and W. C. Corwin.

Splitting of equivalent points in noncentrosymmetric space groups into subsets under homogeneous stress. H. S. Peiser, J. B. Wachtman, Jr., F. A. Munley, and L. C. McCleary.

Inclusion of perfluoromyethyl groups in the crystals of copolymers of tetrafluoroethylene and hexafluoropropylene. L. H. Bolz and R. K. Eby.

Volume 69A (Phys. and Chem.), No. 6 (Nov.-Dec. 1965)

Arc measurement of some argon transition probabilities. C. H. Popenoe and J. B. Shumaker, Jr.

Theoretical interpretation of the third spectrum of gold (Au III). Y. Shadmi.

Photopolarographic behavior of inorganic depolarizers. R. A. Durst and J. K. Taylor.

Spectral structure of critical opalescence: binary mixture. R. D. Mountain.

Irregularities in the NBS (1955) provisional temperature scale. H. M. Roder.

Isotherms determined by the National Bureau of Standards acoustical thermometer in the liquid helium temperature range. G. Cataland and H. Plumb.

Synthesis of D-glucose-*3*-^{14}C and related compounds. H. L. Frush, L. T. Sniegoski, N. B. Holt, and H. S. Isbell.

Correlation of large longitudinal deformations with different strain histories. L. J. Zapas and T. Craft.

Crystallography of tetracalcium phosphate. W. E. Brown and E. F. Epstein.

Electrode potentials in fused systems X. Measurement of cation concentration in molten salts using glass membrane electrodes K. H. Stern and S. E. Meador.

Volume 70A (Phys. and Chem.), No. 1 (Jan.-Feb. 1966)

Optical and magnetic spectra of bis-*N*-propylsalicylaldiminato copper (II). C. W. Reimann, G. F. Kokoszka, and H. C. Allen, Jr.

Phase equilibria in the system niobium pentoxide-germanium dioxide. E. M. Levin.

The solution to a nonlinear Lamm equation in the Faxén approximation. I. H. Billick and G. H. Weiss.

A line formula notation system for coordination compounds: III Deviations from idealized configurations. E. Silverton and R. F. Pasternack.

The spherulitic crystallization of isotactic polypropylene from solution: on the evolution of monoclinic spherulites from dendritic chain-folded crystal precursors. F. Khoury.

Wavelengths, intensities, and Zeeman patterns in ytterbium spectra (Yb I, II, III, IV). W. F. Meggers and C. H. Corliss.

Volume 70A (Phys. and Chem.), No. 2 (Mar.-Apr. 1966)

Mechanism of the depolymerization of polytetrafluoroethylene with pyrolytic and radiolytic initiation. R. E. Florin, M. S. Parker, and L. A. Wall.

Effect of some halogenated hydrocarbons on the flame speed of methane. C. Halpern.

Rupture-disk ampoule for anhydrous addition of hydrogen fluoride. A. R. Glasgow, Jr.

Further studies in the annealing of a borosilicate glass. Sam Spinner and A. Napolitano.

Infrared spectra of the hydrated borates. C. E. Weir.

Interpretation of the solution absorption spectra of the $(PuO_2)^{++}$ and $N_pO_2)^{+}$ ions. J. C. Eisenstein and M. H. L. Pryce.

Vapor pressure and heat of sublimation of rhenium. E. R. Plante and R. Szwarc.

Steady-state response of silicon radiation detectors of the diffused *p-n* junction type to x rays. II: Photodiode mode of operation. K. Scharf and J. H. Sparrow.

Absolute isotopic abundance ratios and the atomic weight of a reference sample of chromium. W. R. Shields, T. J. Murphy, E. J. Catanzaro, and E. L. Garner.

Volume 70A (Phys. and Chem.), No. 3 (May-June 1966)

Thermal relaxation and Brillouin scattering in liquids. R. D. Mountain.

Density of polyethylene crystals grown from solution. G. M. Martin and E. Passaglia.

Mechanical relaxation in polyethylene crystallized with various

degrees of lamellar orientation. J. M. Crissman and E. Passaglia.

Pentafluorophenyl alkyl and vinyl ethers. W. J. Pummer and L. A. Wall.

Calibration of germanium resistors at low temperatures (2–20° Kelvin). G. Cataland and H. H. Plumb.

Dissociation pressure of aluminum carbide using a rotating Knudsen cell. E. R. Plante and C. H. Schreyer.

Determination of intermolecular potential functions from macroscopic measurements. M. Klein.

Volume 69B (Math. and Math. Phys.), No. 3 (July-Sept. 1965)

A development of the theory of errors with reference to economy of time. M. D. Hersey. Prefatory note by Churchill Eisenhart.

Transversal and matroid partition. J. Edmonds and D. R. Fulkerson.

Some L_2 Markoff inequalities. L. F. Shampine.

Some theorems on the permanent. R. A. Brualdi and M. Newman.

On Kirchhoff's law and its generalized application to absorption and emission by cavities. F. J. Kelly.

On a relation between two-dimensional Fourier integrals and series of Hankel transforms. J. V. Cornacchio and R. P. Soni.

On convex metrics. C. Witzgall.

Some extensions of Banach's contraction theorem. P. R. Meyers.

A variant of the two-dimensional Riemann integral. A. J. Goldman.

The use of finite polynomial rings in the factorization of the general polynomial. D. B. Lloyd.

A primal (all-integer) integer programming algorithm. R. D. Young.

Volume 69B (Math. and Math. Phys.), No. 4 (Oct.-Dec. 1965)

Table of Dedekind sums. R. Dale Shipp.

Lattice points in a sphere. M. Bleicher and M. I. Knopp.

Error analysis of phase-integral methods. I. General theory for simple turning points. F. W. J. Olver.

Error analysis of phase-integral methods. II. Application to wave-penetration problems. F. W. J. Olver.

A random walk model of chain polymer adsorption at a surface. II. Effect of correlation between neighboring steps. R. J. Rubin.

Groups of unimodular circulants. R. H. Austing.

A generalization of a result of Newman on multipliers of difference sets. R.L. McFarland.

The bridge tournament problem and calibration designs for comparing pairs of objects. R. C. Bose and J. M. Cameron.
The condition of certain matrices. L. F. Shampine.
Some number-theoretic calculations. K. E. Kloss.

Volume 70B (Math. and Math. Phys.), No. 1 (Jan.-Mar. 1966)

Invariant properties of the spheroidal potential of an oblate planet. J. P. Vinti.
Inclusion of the third zonal harmonic in an accurate reference orbit of an artificial satellite. J. P. Vinti.
On *EPr* and normal *EPr* matrices. I. J. Katz and M. H. Pearl.
The Bernstein form of a polynomial. G. T. Cargo and O. Shisha.
Remarks on measurable sets and functions. R. O. Davies.
The form factor for the Fermi model spatial distribution. L. C. Maximon and R. A. Schrack.
Tables for the evaluation of the Faxén approximation to the solution of the Lamm equation. M. Dishon and G. H. Weiss.

Volume 69B (Math. and Math. Phys.), No. 2 (Apr.-June 1966)

On a sequence of points of interest for numerical quadrature. S. Haber.
On abstract numerical integrations. J. J. Sopka.
Treatment of outliers in samples of size three. F. J. Anscombe and B. A. Barron.
A note on contaminated samples of size three. T. A. Willke.
Realizing the distance matrix of a graph. A. J. Goldman.
Pairs of nonsingular matrices. K. Goldberg.
Upper bounds for the determinant of a row stochastic matrix. K. Goldberg.
Groups preserving ordering in vectors. K. Goldberg.

Volume 69C (Engr. and Instr.), No. 3 (July-Sept. 1965)

Two-terminal dielectric measurements up to 6×10^8 Hz. M. G. Broadhurst and A. J. Bur.
Improved ten-picofarad fused silica dielectric capacitor. R. D. Cutkosky and L. H. Lee.
Errors in the series-aparallel buildup of four-terminal resistors. C. H. Page.
Centerable rotator for measuring properties of crystals. C. P. Saylor and H. B. Lowey.
Equipment for single-crystal growth from the melt suitable for substances with a low melting point. A. T. Horton and A. R. Glasgow.

Phase and amplitude contrast microscopy in partially coherent light. M. De and P. K. Mondal.

Exposure time relations for Kossel microdiffraction photographs. H. Yakowitz and D. L. Vieth.

Cartesian diver as a density comparator. H. A. Bowman and R. M. Schoonover.

Cryogenic behavior of selected magnetic materials. J. J. Gniewek and E. Ploge.

Volume 69C (Engr. and Instr.), No. 4 (Oct.-Dec. 1965)

Some applications of the wave front shearing interferometer. J. B. Saunders.

Precision method for evaluating primary aberrations of lenses with a Twyman interferometer. J. B. Saunders.

Comparators for voltage transformer calibrations at NBS. W. C. Sze.

Voltage dependence of precision air capacitors. J. Q. Shields.

Single crystal x-ray diffraction at high pressures. C. Weir, S. Block, and G. Piermarini.

The Sondheimer-Wilson-Kohler formula in platinum resistance thermometry. R. J. Corruccini.

Stress analysis of tape-wound magnet coils. J. Hord.

Centerline correction for precision roughness specimens. J. L. Chamberlin.

Electric currents and potentials resulting from the flow of charged liquid hydrocarbons through short pipes. M. R. Shafer, D. W. Baker, and K. R. Benson.

A transistor screening procedure using leakage current measurements. G. T. Conrad and D. C. Shook.

Volume 70C (Engr. and Instr.), No. 1 (Jan.-Mar. 1966)

Coulometric calibration of microvolumetric apparatus. G. Marinenko and J. K. Taylor.

Effect of temperature and notch geometry on the tensile behavior of a titanium alloy. W. D. Jenkins and W. A. Willard.

Measurement standards for low and medium peak pulse voltages. A. R. Ondrejka and P. A. Hudson.

Temperature cofficient of rf permeability measurement using an impedance bridge as an equality indicating device. A. L. Rasmussen.

A test apparatus for the study of forced air-mixing devices. T. K. Faison, J. C. Davis, and P. R. Achenbach.

Volume 70C (Engr. and Instr.), No. 2 (Apr.-June 1966)

Design and statistical procedures for the evaluation of an automatic gamma-ray point-source calibrator. S. B. Garfinkel, W. B. Mann, and W. J. Youden.

Testing of lenses with the wave front reversing interferometer. K. Muraoka.

Ellipsoidal mirror reflectometer. S. T. Dunn, J. C. Richmond, and J. A. Wiebelt.

Reference tables for the Pt–30 percent Rh versus Pt–6 percent Rh thermocouple. G. W. Burns and J. S. Gallagher.

Coaxial power meter calibration using a waveguide standard. G. F. Engen.

A note on the numerical evaluation of thermal radiation characteristics of diffuse cylindrical and conical cavities. B. A. Peavy.

Absolute value of g at the National Bureau of Standards. D. R. Tate.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D, No. 7 (July 1965)

International comparison of atomic frequency standards via VLF radio signals. A. H. Morgan, E. L. Crow, and B. E. Blair.

Control of WWV and WWVH standard frequency broadcasts by VLF and LF signals. B. E. Blair and A. H. Morgan.

Measurements of the total electron content and the equivalent slab thickness of the midlatitude ionosphere. R. V. Bhonsle, A. V. da Rosa, and O. K. Garriott.

D-region absorption at 10 and 15 Mc/s during the total solar eclipse of 20 July 1963. G. M. Lerfald, J. K. Hargreaves, and J. M. Watts.

Effect of the eclipse of 20 July 1963 on VLF signals propagating over short paths. J. H. Crary and D. E. Schneible.

A comparison of radar auroral reflection data with acoustic wave theory. Ray L. Leadabrand.

Electromagnetic properties of a plasma covered antenna. D. J. Jacavanco.

Influence of an inhomogeneous ground on the propagation of VLF radio waves in the earth-ionosphere waveguide. J. R. Wait.

Aspects of the terrestrial ELF noise spectrum when near the source or its antipode. L. G. Abraham, Jr.

Analysis of linear arrays focused in the Fresnel region. P. P. Lombardini, R. Doviak, and J. Goldhirsh.

Theory of coil antennas. T. Padhi.

Small prolate spheroidal antenna in a dissipative medium. R. H. Williams, R. D. Kelly, and W. T. Cowan.

Calculated curves for groundwave propagation over inhomogeneous earth with pronounced topographical features. K. Furutsu.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D8 (Aug. 1965)

"Ultra Low Frequency Electromagnetic Fields" Papers

Preface to "Ultra Low Frequency Electromagnetic Fields" Papers. W. H. Campbell and S. Matsushita.

Solar wind and its interaction with the magnetosphere. C. P. Sonett.

Schumann resonances. J. Galejs.

Earth-ionosphere cavity resonances and the propagation of ELF radio waves. J. R. Wait.

Resonances of the earth-ionosphere cavity observed at Cambridge, England. M. J. Rycroft.

Experimental results on the dynamics of the *F* region. W. Becker, R. Rüster, and J. Klostermeyer.

Regular oscillations near 1 c/s observed at middle and low latitudes. L. Tepley.

Preliminary results of a micropulsation experiment at conjugate points. R. E. Gendrin and V. A. Troitskaya.

Some characteristics of geomagnetic pulsations at frequencies near 1 c/s. W. H. Campbell and E. C. Stiltner.

Propagation of hydromagnetic waves in the magnetosphere. M. Sugiura.

Ionospheric perturbation (the roles played by the ionosphere in geomagnetic pulsations). S. Matsushita.

Effects of induced earth currents on low-frequency electromagnetic oscillations. A. T. Price.

Equatorial effects. R. Hutton.

Interpretation of early magnetic transients caused by high-altitude nuclear detonations. S. L. Kahalas and P. Newman.

Abstracts of ULF Conference papers not published in this issue.

Regular Contributions

A note on the application of pulse compression techniques to ionospheric sounding. D. C. Coll and J. R. Storey.

Comments on a paper "Measurement of the phase velocity of VLF propagation in the earth ionosphere waveguide" by F. K. Steele and C. J. Chilton. H. F. Bates.

Reply to H. F. Bates' Comments. F. K. Steele and C. J. Chilton.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D9 (Sept. 1965)

Ground-based passive probing using the microwave spectrum of oxygen. E. R. Westwater.

Response of NBS microwave refractometer cavities to atmospheric variations. R. O. Gilmer, R. E. McGavin, and B. R. Bean.

Effects of rocket outgassing on RF experiments. W. Pfister and J. C. Ulwick.

Further analysis of propagation of plasma waves in a "spoke-wheel" magnetic field. R. R. Gold.

Measurement of group velocity of 17.8-kc/s VLF radio waves. W. D. Westfall.

On the radio noise level at low and very low frequencies in polar regions. T. Stockflet Jorgensen.

Experimental study on the circular loop antenna immersed shallowly in a conducting medium. Keigo Iizuka.

Directivity of uniformly spaced optimum endfire arrays with equal side-lobes. M. T. Ma.

Extension of Fock theory for currents in the penumbra region. V. H. Weston.

Isometric-circle interpretation of bilinear transformation and its application to VSWR minimization. J. G. Rudolph and D. K. Cheng.

Magneto-ionic propagation in inhomogeneous media. Part I. Transverse propagation. B. K. Banerjea.

Magneto-ionic propagation in inhomogeneous media. Part II. Oblique propagation. B. K. Banerjea.

Editorial comment on the scientific papers of Lord Rayleigh (John William Strutt). J. R. Wait.

Radio Sci. J. Res. NBS/USNC, Vol. 69D10 (Oct. 1965)

Irreversible power and radiation resistance of antennas in anisotropic ionized gases. K. S. H. Lee and C. H. Papas.

Scattering resonances of a cylindrical plasma. W. M. Leavens.

Radiation patterns from plasma enclosed cylindrical hypersonic vehicles. J. H. Harris, A. T. Villeneuve, and L. A. Broca.

The Schumann resonances. P. K. Cole, Jr.

Atmospheric radio noise bursts in the LF band at Bangalore. S. V. C. Aiya and K. N. Lakshminarayan.

Influence of finite ground conductivity on the propagation of VLF radio waves. J. R. Wait and K. P. Spies.

Model experiments on propagation of groundwaves across an abrupt boundary at perpendicular incidence. R. J. King and S. W. Maley.

Radio Sci. J. Res. NBS/USNC, Vol. 69D11 (Nov. 1965)

Propagation of pulses in dispersive media. J. R. Wait.

An anisotropic electron velocity distribution for the cyclotron absorption of whistlers and VLF emissions. H. Guthart.

Nose whistler dispersion as a measure of magnetosphere electron temperature. H. Guthart.

Interference rejection capability of a switched radiometer. R. E. Clapp.

Atmospheric breakdown limitations to optical maser propagation. R. G. Tomlinson.

Phase steps and amplitude fading of VLF signals at dawn and dusk. D. Walker.

Propagation in a model terrestrial waveguide of nonuniform height: theory and experiment. E. Bahar and J. R. Wait.

Comments on H. Volland's "Remarks on Austin's Formula." J. R. Wait.

The path integrals of LF/VLF wave hop theory. L. A. Berry and M. E. Chrisman.

Reactive loading of arbitrarily illuminated cylinders to minimize microwave backscatter. K-M Chen.

On the statistical theory of electromagnetic waves in a fluctuating medium (II). Mathematical basis of the analogies to quantum field theory (a digest). K. Furutsu.

Radio Sci. J. Res. NBS/USNC-URSI, Vol. 69D12 (Dec. 1965)

Symposium on Planetary Atmospheres and Surfaces, May 1965:

I Session: Jupiter, as observed at long radio waves.
II Session: Jupiter, as observed at short radio waves.
III Session: Passive radio observations of Venus, Saturn, Mercury, Mars, and Uranus.
IV Session: Passive radio observations of the Moon.
V Session: Radar observations of the planets.
VI Session: Radar observations of the Moon.

Some highlights of the URSI symposium on electromagnetic wave theory held in Delft, The Netherlands, September 6–11, 1965. J. R. Wait.

Technical News Bulletin. This monthly publication summarizes the current research, development, and test activities of the Bureau. The articles are brief, with emphasis on the results of research and their significance, chosen for their importance to other scientists, engineers, and to industry. Résumés of longer research reports, important national and international conferences on fundamental science in which the Bureau has represented the Nation, and bibliography of all publications by members of the staff as published are included. The Bulletin is designed to give a succinct account of the current work of the Bureau. (Annual subscription: domestic, $1.50; foreign, $2.25.)

Monographs. These are usually contributions to the technical literature which are too lengthy for publication in the Journal of Research. They often provide extensive compilations of informa-

tion on subjects related to the Bureau's technical program. Until July 1959 most of this type of material was published in the Circular series.

25. Section 4. Standard x-ray diffraction powder patterns. H. E. Swanson, M. C. Morris, and E. H. Evans. June 28, 1966. 55 cents.
82. Microwave impedance measurements and standards, R. W. Beatty. August 12, 1965. 20 cents.
87. Oxidation of polycyclic, aromatic hydrocarbons. A review of the literature, R. S. Tipson. Sept. 17, 1965. 40 cents.
92. Radio meteorology, B. R. Bean and E. J. Dutton. March 1, 1966. $2.75.
93. Spot diagrams for the prediction of lens performance from design data, O. N. Stavroudis and L. E. Sutton. September 7, 1965. 75 cents.
94. Thermodynamic and related properties of parahydrogen from the triple point to 100 °K at pressures to 340 atmospheres, H. M. Roder, L. A. Weber, and R. D. Goodwin. August 10, 1965. 75 cents.
95. A table of radiation characteristics for uniformly spaced optimum endfire arrays with equal sidelobes, M. T. Ma and D. C. Hyovalti. December 10, 1965. 45 cents.

Handbooks. These are recommended codes of engineering and industrial practices, including safety codes, developed in cooperation with the national organizations and others concerned. In many cases the recommended requirements are given official status through their incorporation in local ordinances by State and municipal regulatory bodies.

44. 3d edition. Specifications, tolerances, and other technical requirements for commercial weighing and measuring devices. October 12, 1965. (Supersedes Handbook 44, 2d edition.) $2.00.
100. Copper wire tables. February 21, 1966. (Supersides Cir. 31.) 50 cents.
101. OMNITAB. A computer program for statistical and numerical analysis, J. Hilsenrath, G. G. Ziegler, C. G. Messina, P. J. Walsh and R. J. Herbold. March 4, 1966. $3.00.

National Standard Reference Data Series. NSRDS provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Reports will fall into eight categories: general; nuclear properties; atomic and molecular properties; solid state properties; thermodynamic and transport properties; chemical kinetics; colloid and surface properties; and mechanical properties of materials.

4. Vol. I. Atomic transition probabilities. Hydrogen through neon, W. L. Wiese, M. W. Smith, and B. W. Glennon. May 20, 1966. $2.50.

Miscellaneous Publications. As the name implies, this series includes material which, because of its character or because of its size, does not fit into any of the other regular publication series. Some of these are charts, administrative pamphlets, Annual Reports, Weights and Measures Conference Reports, and other subjects appropriate to the Miscellaneous series.

236. NBS standard frequency and time services, 1966 edition. (1966). (Supersedes previous editions). 15 cents.
250. Calibration and test services of the National Bureau of Standards. 1965 Edition. Oct. 28, 1965. (Supersedes 1963 edition.) $1.00.
260. Standard Reference Materials: Catalog and price list of standard materials issued by the National Bureau of Standards. October 1, 1965. 45 cents.
260–6. Standard Reference Materials: Methods for the chemical analysis of white cast iron standards, J. I. Shultz. July 16, 1965. 45 cents.
260–7. Standard Reference Materials: Methods for the chemical analysis of NBS copper-base spectrochemical standards, R. K. Bell. October 25, 1965. 60 cents.
260–8. Standard Reference Materials: Analysis of uranium concentrates at the National Bureau of Standards, M. S. Richmond. December 1, 1965. 55 cents.
260–9. Standard Reference Materials: Half lives of materials used in the preparation of standard reference materials of nineteen radioactive nuclides issued by the NBS, S. C. Anspach, L. M. Cavallo, S. B. Garfinkel, J. M. R. Hutchinson, and C. N. Smith. November 15, 1965. 15 cents.
260–10. Standard Reference Materials: Homogeneity characterization of NBS spectrometric standards II: Cartridge brass and low-alloy steel, H. Yakowitz, D. L. Vieth, K. F. J. Heinrich, and R. E. Michaelis. December 14, 1965. 30 cents.
269. Statistical association methods for mechanized documentation. Symposium Proceedings Washington 1964, M. E. Stevens, V. E. Giuliano, and L. B. Heilprin. December 15, 1965. $2.75.
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275. Measures for progress. A History of the National Bureau of Standards, R. C. Cochrane. 1966. $5.25.
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18–24. Quarterly radio noise data September, October, November, 1964, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. February 10, 1966. (Formerly the Central Radio Propagation Laboratory of the National Bureau of Standards, now Environmental Science Services Administration, Boulder, Colorado.) 50 cents.

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262. Accuracy in measurements and calibrations, 1965, W. A. Wildhack, R. C. Powell, and H. L. Mason. June 15, 1965. $1.00.

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267. Procedures for precise determination of thermal radiation properties, November 1963 to October 1964, J. C. Richmond, S. T. Dunn, D. P. DeWitt, and W. D. Hayes, Jr. Dec. 17, 1965. 45 cents.

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270–2. Selected values of chemical thermodynamic properties. Part 2. Tables for the elements twenty-three through thirty-two in the standard order of arrangements, D. D. Wagman, W. H. Evans, I. Halow, V. B. Parker, S. M. Bailey, and R. H. Schumm. May 6, 1966. Supersedes NBS Circ. 500. 40 cents.

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329. The seasonal variation of nightglow Nal 5890–96A, (01) 5577 A and (01) 6300 A in the tropics, L. L. Smith and R. W. Owen. January 10, 1966. (Formerly the Central Radio Propagation Laboratory of the National Bureau of Standards now the Environmental Science Services Administration, Boulder, Colorado.) 35 cents.
330. Computations of the antenna cut-back factor for LF radio waves, D. C. Hyovalti. November 26, 1965. (Formerly the Central Radio Propagation Laboratory of the National Bureau of Standards now the Environmental Science Services Administration, Boulder, Colorado.) 30 cents.
331. A 100 KW 2–25 Mc/s distributed amplifier, designed for use with 10 KW ionospheric sounders, W. B. Harding, M. W. Woodward, and J. C. Carroll. February 15, 1966. (Formerly

the Central Radio Propagation Laboratory of the National Bureau of Standards now the Environmental Science Services Administration, Boulder, Colorado.) 20 cents.

332. Carbon dioxide spectral line positions and intensities calculated for the 2.05 and 2.7 micron regions, R. F. Calfee and W. S. Benedict. March 15, 1966. 60 cents.

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334. (PB173291) An introduction to sampled data and switching logic, T. L. Davis. April 1, 1966. (Formerly Central Radio Propagation Laboratory of the National Bureau of Standards, now Environmental Science Services Administration, Boulder, Colorado.) $3.00.

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339. Observed phase-front distortion in simulated earth-to-space microwave transmission, H. B. Janes and M. C. Thompson, Jr. May 12, 1966. (Formerly the Central Radio Propagation Laboratory of the National Bureau of Standards, now the Environmental Science Services Administration, Boulder, Colorado.) 50 cents.

341. The long-term performance of two rubidium vapor frequency standards, B. E. Blair and A. H. Morgan. June 22, 1966. 25 cents.

342. Hydromagnetic wave propagation near 1c/s in the upper atmosphere and the properties and interpretation of Pc 1 micropulsations, J. A. Dawson. June 30, 1966. (Formerly the Central Radio Propagation Laboratory of the National Bureau of Standards, now the Environmental Science Services Administration, Boulder, Colorado.) 40 cents.

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PATENTS

The following U.S. Patents have been granted to NBS inventors; assigned (or licensed as indicated) to the United States of America, as represented by the Secretary of the Department noted in parentheses:

Bowen, Rafael L., No. 3,194,783, July 13, 1965. Silica-Resin Direct Filling Material and Method of Preparation. (Commerce)

Bowen, Rafael L., No. 3,194,784, July 13, 1965. Silica-Resin Direct Filling Material and Method of Preparation. (Commerce)

Bowen, Rafael L., No. 3,200,142, August 10, 1965. Surface-Active Comonomer and Method of Preparation. (HEW)

Jamieson, Ballard and Kee, Robert, No. 3,202,042, August 24, 1965. System for Measuring Separately Background and Average Line Luminance or Density. (Commerce)

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